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ON THE TEACHING OF ANATOMY AS ILLUSTRATED BY PROFESSOR BARKER'S MANUAL.[1]

By FRANKLIN P. MALL.

Professor Barker has given us a profound work upon the nervous system and an excellent English edition of Spalteholz's superb Atlas of Human Anatomy. To these he now adds a laboratory manual of anatomy, one of the best dissecting-room guides which has ever been published.

With the exception of those in a few medical schools the dissecting-room is a pretty poor specimen of a laboratory, due mainly to the lack of competent instructors. The course is generally "go as you please," and in order to accomplish anything it requires students of ability and earnestness with a power to plan ahead, and for them Barker's Manual will be a great aid. From it they will receive guidance, which otherwise could be received only from competent teachers. The Introduction to the Manual points out to the student the well-known methods for unraveling the human body, by which they obtain knowledge at first hand. "Careful practical work in the dissecting-room is the only means a medical student has of obtaining an independent view of the gross structures of which the body is composed. He should learn to *see* what comes under his eye. He should try by his own independent activity to see all that is there, for the student who learns to see only what he is told to see, or what is pointed out to him, will be spoiled for the study and the practice of medicine." Professor Barker seems to ignore wholly that anatomy (?) which consists of memory feats brought about by drill masters who have prepared the student for no one knows what. "The very first dissection," he says, "may be all-important as regards the subsequent dissections. He who fails in his earliest dissection to acquire the habit of working according to a definite method, seldom learns later to become an exact, quick, and careful dissector. It is almost hopeless to try to make a

[1] A Laboratory Manual of Human Anatomy. By Lewellys F. Barker, M. B., Tor., Professor and Head of the Department of Anatomy, in the University of Chicago and Rush Medical College. Assisted by Dean De Witt Lewis, A. B., M. D., and Daniel Graisberry Revell, A. B., M.B., Instructors in Anatomy in the University of Chicago. 8vo. 583 pages and 298 illustrations, many in colors. (Philadelphia: J. B. Lippincott Company, 1904).

man do exact and clean work in the dissecting-room after he has once formed inaccurate and dirty habits.... If a dissector permit himself to expose structures roughly, to isolate them incompletely, and to clean them imperfectly, so that his dissection becomes indistinct, bad-smelling, and repulsive-looking, he will quickly lose interest in his work, slice the part desperately, neglect it, stay away from it, and fail utterly to benefit by it. . . . The thorough dissector is much more likely to become a fine discriminating physician and an effective, progressive surgeon." Not one word do we read in this excellent book about memorizing names, systems of mnemonics, quiz-classes and final examinations. Nowhere do we read that the 5000 questions which were placed before me while a medical student gives the "royal road" to knowledge.

The book is written as a guide to earnest students who, with the aid of good teachers, desire to dissect the human body and thereby obtain a conception of it. If a student wishes to study anatomy he is most successful when he obtains his knowledge through actual experience in the dissecting-room, and to do this he must learn to unravel the structures of the body, and to see, classify and describe what he has done. While working thus he is naturally led into the literature of the subject which, when drawn upon later in life, should enable his imagination to see the part described in three dimensions of space.

The methods of isolating the structures of the human body have been well established, and certain rules for dissection have been formulated. These rules are well known to anatomists, and it is best for the students when they are taught them by the most experienced teachers. To do this the teachers must accompany the students in their daily work, and unless this is the case the ship will run upon the rocks, even if the nautical almanac and the quadrant are in the hands of the sailors. It is the ideal of the instructor, the word here and the word there, that means so much to the student. The great bulk of the time of the student is to be occupied by his own work—dissecting, reading, drawing, comparing and reflecting—and here the Manual may help out immensely. In it the thousand and one hints are given, and questions are answered in order, as in a dictionary. Professor Barker has written what the teacher says many times, and I shall be much gratified if, in future, it saves me some words.

In arranging the material, Barker has followed closely the order given in Cunningham's Manual, thus enabling the student to use both books at the same time. The steps and technique are to be gotten from Cunningham, while the hints and directions for study are found in Barker's Manual.

It is possible to classify the teaching of anatomy in America under four heads.

The first and lowest order is found in those schools which give a course of crude lectures on anatomy with a dissecting-room in which the work is not directed, but is done in a superficial way. Often the students do not dissect at all. At best they use a brief guide or a quiz compend which enables the students to "learn enough" to pass the examinations. Barker's Manual will be of no use—will be wholly lost—to both students and professors in medical schools which conduct their course in anatomy in this way.

The teaching of anatomy is of a higher order when it follows closely some text-book, especially Gray, when it has lectures and recitations and enough work in the dissecting-room to enable the students to identify the grosser structures, thereby giving enough information to enable the students to pass State examinations. Most of the medical students desire courses of this order. Barker's Manual will be of little value to them, but it is to be highly recommended to their teachers, for through them it will do the greatest good.

In a third and higher order of medical school, about twenty of which may be counted, the course is given to aid the students in their subsequent medical studies. Practical things are pointed out in lectures, and emphasized again in the dissecting-room, and finally the student is examined upon them. Both students and teachers work pretty hard, and at the end of the course all feel that much good has been done.

A professor told me recently that he made his course "truly practical" by teaching only the essentials which he learned, by canvassing all of the clinical teachers. What they considered essential was taught, and what was considered unessential was excluded from the course. This practical knowledge he drilled into his students by means of lectures, quizzes, and thorough work in the dissecting room, and the results were most satisfactory to all concerned. To him and to his better students I most cordially recommend Barker's Manual. It will give them something to think about, and by that very effort will do them much good.

In the fourth order of anatomical course it is considered that there are others to be satisfied besides the teachers in a few practical branches,—there are the teachers in the other sciences, physiology, neurology, pathology, as well as anatomy itself. A student told me recently that he had been studying one thing to help him in another all of his life, and he was dead tired of it; he now desired to study things that were worth studying for their own sake. For him anatomy could not be considered an ancillary science. In presenting a science to students no attitude can be defended, except that in which the science is studied for its own sake. In so doing the development of the student cannot possibly be ignored, for understanding and self-development go hand in hand.

"Many students in the past have entered the dissecting-room with an utter lack of independent power of observation, of examination and of description, and yet these three qualities are absolutely necessary for the man who is to engage successfully in the practice of medicine. While it is to be hoped that the advance in the requirements for admission to professional schools, leading as it does to observational work in physics, chemistry and biology preliminary to the work of the medical course, will bring the students to our laboratories of anatomy better prepared than hitherto for the independent observation of anatomical structures, there can still be but little doubt that many students will learn how really to study and observe first in the dissecting-room. How important it is that the habits formed at this early period of the profes-

FIG. 1.—Maximum protrusion in profile.

FIG. 2.—Maximum protrusion, three-quarters face.

FIG. 3.—Profile of left side.

ERRATUM.—This plate should have been inserted in the BULLETIN for January, 1905, opposite page 12.

sional course should be such as will be of value to the student later, such as he would desire to have throughout his professional career! If he have learned to be exact and steady, systematic and thorough, cleanly and artistic in his work in the dissecting-room, how much better for him than if at the outset of his career he become satisfied with superficial observation, with interrupted and irregular activity, with disorder and uncleanliness! The habits formed in the anatomy building have their effect upon the whole life of the physician. The student in the beginning should aim not so much at rapidity as at method. When he has once formed the habit of proceeding always according to a careful method, the rapidity will quickly follow.

"It is sometimes asked: 'Why should the medical student spend so much time and take so much pains in making a careful and beautiful dissection? Is it not time wasted to work out the smaller branches of the nerves and blood-vessels?' Experienced teachers who require thorough work are not disturbed by such inquiries. Those who have had the best opportunity for judging assert that it is only when a man succeeds in making a fine dissection that he gains an interest and pleasure in an occupation, which may not at first be attractive to him. Further, the impotance of working out the finer structures lies not always so much in the actual knowledge of these structures gained by the student, as in the acquisition of the habit of thoroughness of observation and investigation. The medical student who in the dissecting-room dissects out only the main trunks of the vessels and nerves, or only the structures which, at the moment, seem to physicians and surgeons of greatest practical import, is likely, as a clinician, to be satisfied with the detection of the more obvious and superficial symptoms, to the overlooking of the less prominent symptoms and the more obscure physical signs."

It is especially for students and teachers of anatomy in the best medical schools that Barker's Manual will be of great value.

It is generally admitted that the most valuable training in anatomy is obtained in the dissecting-room, and it is in this place where the best teaching can be done. The instructor, text-books and manuals are only aids to be used as guides. The main effort must be on the part of the student, for it is he who is to obtain the knowledge through his senses. He must unravel the structures, arrange and classify them, reflect over them and express them, best by means of drawings, in order to get the most out of his work. His work is easy in proportion to his power to see in three dimensions of space, and to aid this models and pictures are to be used. It happens, also, that anatomy has an extensive language of its own and he must acquire some of this in order to express his knowledge of the subject in words, as well as to gain command of its extensive literature. While a few will excel, every student must be able to do this in part at least, before he is proficient in anatomy.

It is relatively easy to dissect the human body successfully, and when a student can attach names to the structures he has dissected he is usually satisfied. The second step, studying the part is the difficult one, one that is mastered by but few students. The movement in anatomy in America during the past twenty years has been to make the study inductive, just as Huxley would have it, and in order to bring this about students have been introduced to anatomy in the dissecting-room rather than in the lecture-room. My own experience is that nearly all students can be made good dissectors in less than a week, and many of them in a day, but it takes a number of weeks before they are able to get the full benefit of their own dissections. If, with pictures to aid the imagination, they can look ahead and if, with pencil they draw what they have dissected, they have accomplished much for they work independently. Such students the instructor can aid with advice, he can discuss next steps with them, he can aid them in reading and in drawing, all of which he does with the greatest of pleasure. But many students do not have this gift and to teach them is difficult. Barker's Manual not only helps them, but does not retard the talented students. Superficial students can never use it as a quiz-compend, nor can it be memorized. In the description of the back, for example, Barker says on page 45:

"Reflect the two triangular flaps of skin, taking none of the fat of the superficial fascia with it. Have your atlases open before you. Having ascertained the region in which the medial set of cutaneous vessels and nerves is likely to be found, with the knife make a small cut through the superficial fascia down to the deep fascia. With the special heavy probe recommended, separate an area of the superficial fascia until you encounter the trunk of a blood-vessel or a nerve coming through the deep fascia from below to enter the superficial fascia. It is common to find a nerve, an artery and a vein together. Carefully separate the structure or structures found from the superficial fascia, tracing the blood-vessel or nerve as far as possible and cleaning it thoroughly. In this way, isolate all the superficial blood-vessels and nerves in the medial and lateral areas in which they occur. The nerves and blood-vessels will be found emerging through the deep fascia. Their course and ramifications in the superficial fascia are to be traced out without removing the fat or disturbing the relations of the structures any more than is necessary in exposing them. It should be borne in mind that it is only the natural relations that are of importance, and not the artificial relations due to dissection. Hence, each structure should be studied as it is worked out, instead of its study being deferred until after it is isolated and cleaned. When the cutaneous nerves and vessels and superficial glands have been thus exposed, a drawing of these should be made; or the drawing may be made concurrently with the dissection, being then an aid to the determination of the exact relations.

"The deep fascia should be cleaned (by careful removal of the superficial fascia by blunt dissection) and its extent, nature and attachments studied. The fasciæ should then be removed piece-meal. In cleaning the surface of the muscles, place the body in such a position that the muscle-fibers will be rendered tense and carry the knife in the direction which

permits removal of the fascia with the least disturbance of the underlying muscle. Care should be taken to avoid giving a ragged appearance to the surface of the muscle. As soon as the trunk of a nerve or blood-vessel is found, ascertain its name from a study of the illustration in your atlas. Look up this name in the index to your Systematic Human Anatomy and refer to the author's description. When handling a nerve, blood-vessel or indeed any structure, form the habit of repeating to yourself its name; this practice is extremely helpful in fixing the association between the structure and the name which is the sign for it. Also, when reading, write down every new term met with and learn its meaning, both literal or etymological and applied or derived."

After this there follows a list of nerves, arteries, veins and muscles in the order of their appearance, with reference to figures in the Manual as well as in Spalteholz's Atlas and other books. The subject is presented just as if the reader really wanted to study anatomy. It is illustrated with 298 figures, in great part taken from Toldt's Atlas, and from Poirier and Charpy's Anatomy.

Throughout the Manual the new nomenclature is used with the old names, when they differ much, placed in brackets. Both English and Latin terms are given. In my opinion, it would be better if only the anglicized new nomenclature were given, much as has been done in Cunningham's Anatomy. The international terms (Latin) can be found easily by referring to Spalteholz, which is to be used in connection with this Manual. However, it is very desirable that the new nomenclature should be used, for then the student commands a language of anatomy which is not only English but is also international.

The names in anatomy were introduced by many authors during past centuries, which naturally led to the formation of numerous synonyms. Over a century ago this chaotic condition was deplored by Sömmering (Bau des menschl. Körpers, S. XII, 1800), who then suggested that anatomists construct a uniform nomenclature as the botanists had done. But each new attempt brought only a new set of synonyms, for there was no Linnaeus in anatomy who could do the work. The numerous names then, as at present, made the study of anatomy very much more difficult than it would be were the terminology simple and rational. At that time, Dumas (1797) attempted to make it rational, however, without success, as is the case with Wilder's nomenclature in recent years. A great authority, as a congress, was necessary to bring about this reform. Henle (Anatomie, S. VII, 1858) revised the list of names very markedly, placing the synonyms in foot-notes, not using them indiscriminately as pedants love to do. His reform did much good and also caused much confusion; we have to thank him, however, for the terms, dorsal, ventral, sagittal, frontal, medial and lateral. Later, Owen added to them the terms, distal and proximal.

Finally, the suggestion of Hyrtl (Anatomie, S. 35) bore fruit. He proposed that the Naturforscher Gesellschaft, from which the Anatomische Gesellschaft sprang, take up the subject and give the nomenclature of anatomy a thorough scientific and philological revision. This was finally done, under the leadership of His. The international committee, with Sir William Turner, Cunningham and Thane to represent England, supported by the Academies of Berlin, Munich, Vienna, Leipsic and Buda-pest, and the Anatomische Gesellschaft, after six years of hard work, finally rendered a satisfactory report (see His, Nomina Anatomica, 1875), which has been accepted generally by the anatomists of the world. In our language we have a number of comparative anatomies, two very important atlases (Spalteholz and Toldt), a text-book (Cunningham, in part), and now Barker's Manual which uses this terminology. Students, physicians and some professors think something radical has been done, and fear that if they accept it they must unlearn something,—they know not what,—but when they realize that it is the Italian, the German, the Swede and others must change their terminology much more than the Englishman, they will welcome the new language. It differs less from our terminology than from that in any other language. The His nomenclature (BNA) has reduced the 30,000 anatomical terms to 5000, and of them 4500 are the same as the English terms. Of the 500 terms which differ from the old, the change is usually slight. Nearly all of the radical changes were made in the neural terms, and in general these have been accepted by all writers. Had Barker anglicized the names of BNA, but few readers of the Manual would notice that he has used the new nomenclature.

It is to be hoped, in the interest of anatomy and scientific medicine, that Barker's Manual will receive a wide circulation.

THE ANATOMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA.

By Joseph Marshall Flint, M. D.

In the past few decades many papers have been published upon the ends and aims of anatomy, as well as upon its pedagogical methods and the construction of laboratories in which it is taught. These articles cover this field thoroughly and well. It seems, therefore, quite unnecessary to make another contribution to this, already, large literature. Hitherto, most of the larger anatomical institutes have been constructed anew where the director has had an opportunity to express his ideas entirely unhampered by already existing structures. As it is sometimes necessary, however, to reconstruct or readapt buildings already in existence for the use of an anatomical department, our experience in the University of California may have some new interest and possibly some practical bearing. Here, it was essential to rearrange the quarters in a

building, planned for the medicine in vogue before the extensive introduction of the laboratory system. It may be well to state, however, that these rooms lent themselves admirably to our needs. It is, indeed, probable that most quarters supplied with adequate space and light could be transformed into a serviceable laboratory adapted to the needs of modern anatomy. In the rearrangement of the space at our command, attention was paid to the following objects: First, the necessities of teaching and, secondly, facilities for research. Under these two heads and their ramifications, all the needs of anatomy may be supplied. It was deemed wise to provide space and equipment for a class of 50 students, although our maximum attendance in any one class has thus far been but 42.

Naturally, in anatomy, as in other educational branches, the chief essentials of equipment are men and not rooms nor microscopes. In this country, for some reason, it has been difficult to preserve a proper ratio between staff work and equipment. In some institutions splendid equipments are insufficiently manned, while in others it is often true that good men are handicapped either by a lack of materials with which to do their work or else are overburdened with excessive routine. Perhaps we are in what one college president terms "The Stone Age," in which our university resources are too apt to crystallize into bricks and mortar instead of contributions to the various fields of science. According to A. G. Mayer's[1] recent study on the material and intellectual development of American universities, things have not improved much in the last decade; but in the case of the medical branches of university life, there has been a noticeable exception. In recent years, particularly in the so-called scientific branches of medicine, several well-equipped and well-manned laboratories have been established. Indeed, there seems to be a general tendency to conduct the first two years of medicine at least upon a university basis. This means, in addition to routine teaching, a portion of the energy of the department must be spent in productive scholarship. In the University of California members of the anatomical staff are expected to devote one-half of their time to research.

The building, in which the Medical Department of the University of California is sheltered, was constructed for the University by the State of California, in 1898. It consists of a substantial three-story building, constructed of granite and buff brick, situated on Parnassus heights and commanding a magnificent view of the Pacific Ocean and the bay of San Francisco. The old quarters allotted to anatomy were on the top floor, where one large dissecting-room with roof light and a few smaller rooms were allotted to the students in anatomy. Additional space on the lower floors was obtained for an histological laboratory, store-rooms, and photographic-room. Adequate room in the basement for the embalming and preservation of anatomical material was arranged in the first plan of the building.

[1] Material versus Intellectual Development of our Universities. Science, Vol. XX, 1904.

DISSECTING-ROOMS.

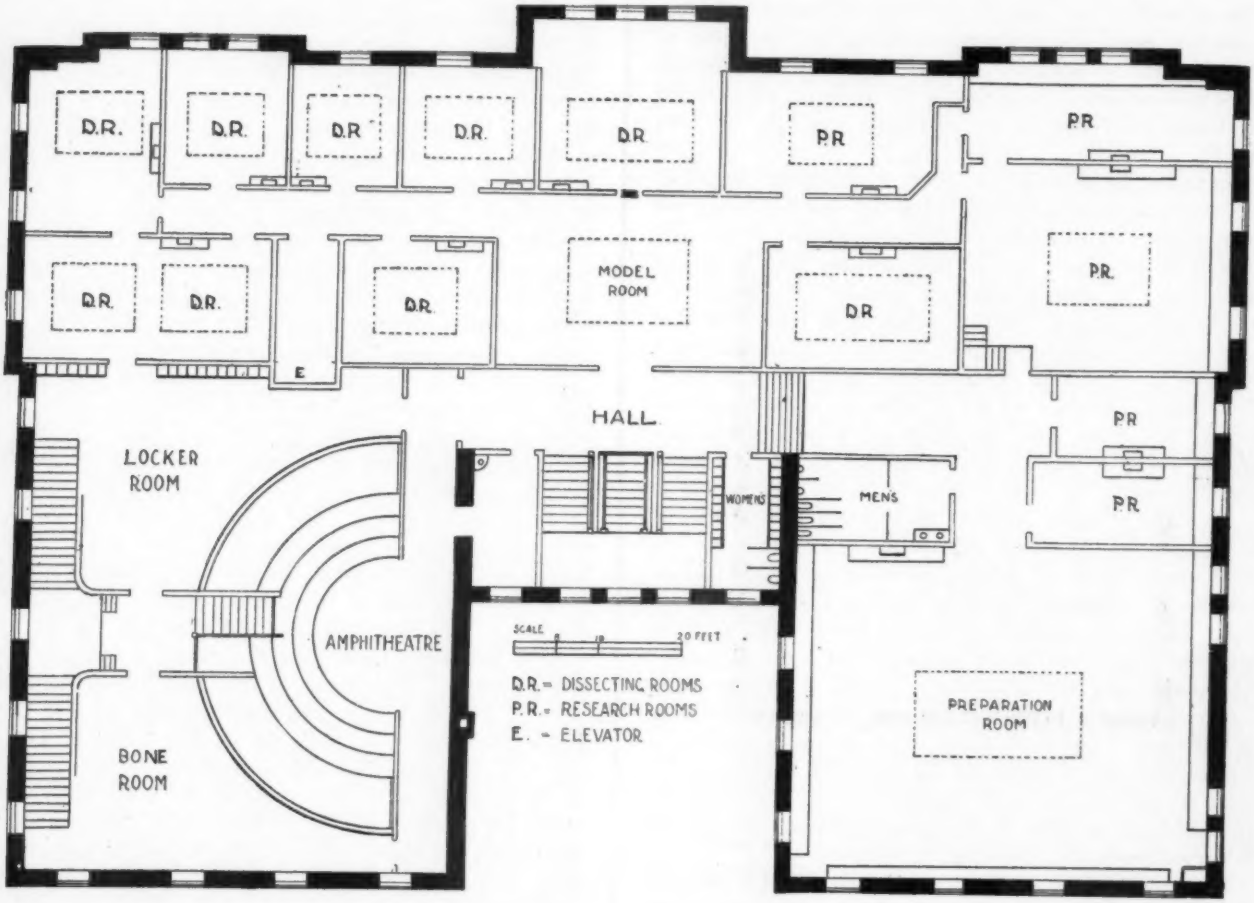
The large dissecting-room was provided with roof light, a tarred floor and rough brick walls. In the conversion of this space to more modern dissecting-rooms several points concerning anatomy in this country had to be borne in mind. In the first place, anatomical material was often poorly preserved and frequently scant in quantity; in the second, by tradition, students who crossed the threshold of a dissecting-room assumed at times that they were absolved from all standards of good conduct. Hats were worn; students dressed in outlandish costumes. Smoking was generally permitted, and boisterous conduct, accompanied by the throwing of material were not infrequent occurrences. To break this tradition and to obtain in a measure the morale and seriousness characteristic of the students in other departments of the university, we profited by the experience of Professor Mall of the Johns Hopkins University, who, in the construction of his laboratory, went on the assumption that students should be divided into small groups and should be provided with dissecting-rooms, which resemble a modern laboratory more than they do a stable. Accordingly, the large dissecting-room was re-covered with a new floor, and was cut up into a series of small rooms, each, with a capacity of from 1 to 4 tables, thus segregating small groups of students. In this way fewer distractions occur and one obviates the inevitable noise that occurs when even larger bodies of well-behaved students are quartered in the same laboratory. The rooms, moreover, were fitted with especial care to make them clean, neat, and attractive, hoping in this way to obtain the effect of a pleasant environment upon the work of the students during the periods of dissection. The large room was 35 by 110 feet, and was subdivided into eight small dissecting-rooms, a research room and a museum. The largest of these small dissecting-rooms is 20 by 21 feet, with a comfortable capacity of four tables and a maximum of six, while the smallest is 12½ by 15 feet, and holds one dissecting table conveniently. The remainder are so arranged as to hold from one to three tables. The rooms are provided with heavy tables with zinc tops, draining toward the center into a bucket suspended beneath the table. Adjustable arm-rests and book-stands also form part of the equipment. As soon as the body is cut in parts, students are no longer forced to work together, and in consequence one or two small tables with book-stands are provided in each dissecting-room. There is a sink with running-water and a large drip-board to hold parts while they are being moistened, or for the study of the viscera. Each room has, besides, an articulated skeleton for convenient reference and a blackboard upon which schemata may be drawn and relations studied. During the period of dissection the student is held responsible for his material, which must be carefully wrapped in cheesecloth at the close of each laboratory period. These wrappings are moistened in a solution of carbolic acid, glycerine and water, made according to the following formula:

Water	1000 cc.
Glycerine	30 cc.
Carbolic Acid	20 cc.

This procedure prevents desiccation and, at the same time, acts to a certain extent as a preservative.

The Museum.

No space was available for use as a museum and, accordingly, the entrance hall to the dissecting-rooms was left large for this purpose. Its dimensions are 20 by 32 feet and it contains sixteen unit museum cases for the exhibition and storage of models that are used either for demonstration or teaching purposes. Here also are kept the most interesting variations which have been found from time to time in the dissecting-rooms, as well as examples of research work which has been done by students and members of the teaching staff. The latter are valuable for the purpose of demonstration, and often act as a stimulus for more serious students to engage in research work. The location of the museum in this hall, which was forced upon us by lack of space in other parts of the building, has proved most fortunate. In the experience of most laboratory workers, students in the attendance upon regular courses very rarely avail themselves of the opportunities afforded by a museum. The interest in such specimens is not sufficient to overcome the inertia of any but the best students. But if exhibition cases are so placed that they must be passed in going to and from the regular work, specimens are frequently studied when, under ordinary circumstances, they would not be seen. In the course of a year's work, students register many thousands of visual impressions simply in passing back and forth. The museum is provided with two large unit tables for the study of its preparations, but these are naturally exposed to the noise caused by students in transit. Were I to build a laboratory anew, I should consider as one of its most important features the placing of the museum in the main thoroughfare of the laboratory. At the same time it would be advisable to have at one side an exhibition room where specimens could be studied in quiet. During the three



RESEARCH AND DISSECTING ROOMS
DEPARTMENT of ANATOMY

Fig. 1.

years that the laboratory has been opened, students have developed a morale which enables us to trust them with the models. And, considering the amount of handling they have had, the breakage has been remarkably small. Among other things the museum contains the usual sets of teaching models of His manufactured by Ziegler of Frieburg, and Steger of Leipzig.

PREPARATION OF MATERIALS.

The embalming-room is situated in the basement, and is reached by a private driveway, which secures privacy in the reception of cadavera. The embalming-room is provided with a hydraulic-pressure apparatus, modeled after the one in the anatomical laboratory of the Johns Hopkins University. It consists of an ordinary water-boiler, provided with controlled outlets and intakes, a pressure gauge and a pipe at the top to conduct compressed air. The embalming and injection fluids

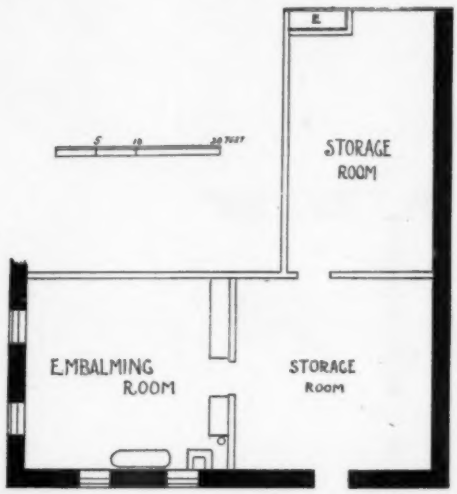


FIG. 4.—PLAN OF EMBALMING AND STORAGE ROOMS.

are forced from aspirator bottles, through rubber tubing canulæ, into the body at any desired pressure. The material received by this department comes almost exclusively from the Almshouse. The subjects are, as a rule, very old, and owing to the activity of certain religious organizations which insist on the burial of females, consist almost exclusively of males. The embalming is done through both distal and central ends of the femoral arteries. At first, we embalmed from one side alone, but experience soon showed that the advanced degree of arterio-sclerosis in these subjects often made it impossible to preserve both extremities well unless the injection is made through both femorals. The fluid is forced into the vessels from the injection flask under a pressure of about five or six pounds to the square inch, by means of a series of Y-tubes terminating in cannulæ. After the body is injected it is allowed to remain for 24 hours, and then coloring matter is forced into the vessels. At first both arteries and veins were injected; subsequently the venous injection was abandoned, as the inevitable tearing of small veins in order to clean up a dissection gave it a very dirty appearance. With the single arterial injection, these vessels stand out clearly differentiated from the collapsed veins, which can be easily seen and preserved in an average dissection. After the vascular injection is complete, the calvarium is opened and the brain removed for use in the course in neurology, in which each student sections at least one complete encephalon. Several methods of embalming have been used. The earliest was an arsenic-formalin mixture which preserved the body excellently; but, like most formalin embalming fluids, tended to make the arms and legs stiff and rigid. The abduction of the extremities necessary for the dissection of the axilla and perinæum frequently ruptured the pectoralis major and the abductors of the legs. Moreover, this material frequently became discolored, the differentiation between the muscles and the surrounding structures was not distinct, and finally they seemed to be particularly liable to infection with moulds. Struther's fluid was also used, and in many instances gave great satisfaction. In cadavera preserved by this method the differentiation of the fascia is exquisite; but, in many of them, the coagulation of the myosin is incomplete, leaving the smaller muscles soft and friable. Thus it became quite difficult to preserve them without tearing or distortion throughout the dissection of a part. The carbolic mixture advocated by Mall we employ now almost exclusively. By its use the preservation and differentiation of the various structures seems on the whole best. Moreover, bodies preserved by this method are practically odorless, and can be left exposed to the air for months during dissection without either moulding or undergoing putrifaction. The material has been preserved in two ways, one in wood alcohol vapor and the other by means of immersion in a 3 per cent solution of carbolic acid. For both purposes, zinc-lined wooden tanks are used, varying in capacity from 7 to 14 bodies. The most convenient tanks, in our experience, are 50 inches wide, 27 inches deep, and 6 feet 4 inches long. These tanks have a capacity of 14 bodies. After a careful comparison it seems that the wood alcohol vapor, while efficient, is more expensive and also has the disadvantage of allowing an extreme mummification of the extremities to take place. In bodies, however, where the hands and feet have become almost completely desiccated, or where the skin is tough and leathery, after they have been exposed to the vapor of wood alcohol for a period of two years, we have succeeded in restoring flexibility to the extremities by means of immersion in hot water. When bodies are in this condition, we place them for a period of 12 to 48 hours in a porcelain bath-tub full of water at a temperature of about 60° Centigrade. The fluid is taken up and the hands and feet rapidly soften. By far the best of our material, however, has been that preserved by immersion in a 3 per cent solution of carbolic acid. At present we have over 100 bodies stored in this way, some of which have been in the fluid for eighteen months. The skin becomes particularly well fixed, rendering it useful in the preservation of material from desiccation through a large portion of the period of dissection. The method also has the advantage of being economical. A string

is tied around the neck of each subject to which is attached the body number held upon a cork. This floats upon the surface of the tank. It is possible, therefore, by simply referring to our card catalogue of anatomical material to recover any body at will. Above the tanks is a rail suspended from the ceiling; a wheel to which is attached a block and tackle travels on this track. It is a simple matter for one person to handle and care for the material by means of this tackle. An elevator runs from the storage-room in the basement to the dissecting-rooms on the top floor. In the embalming-room, there is also a macerating tank, for the preparation of skeletons from the finished dissections.

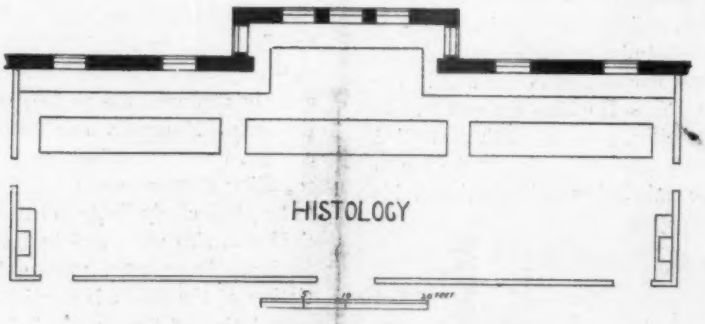


FIG. 9.—PLAN OF HISTOLOGICAL LABORATORY.

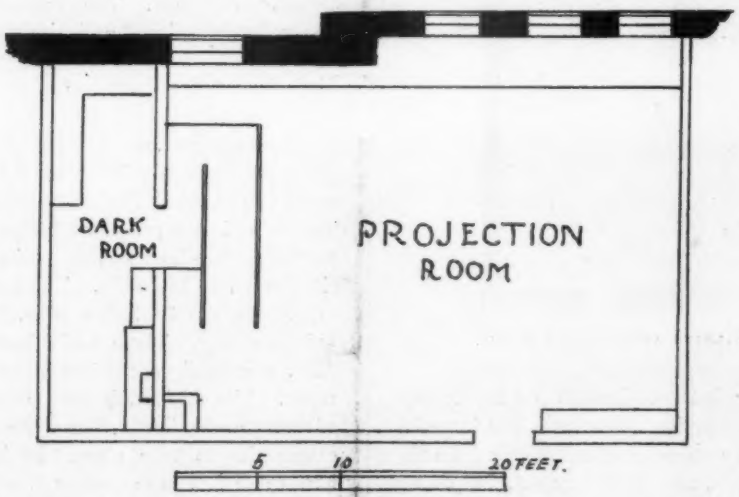


FIG. 11.—PLAN OF PROJECTION ROOM.

THE PREPARATION ROOM AND THE RESEARCH ROOMS.

On the top floor, in a wing opposite the amphitheater and dissecting-rooms, are the research rooms and preparation room. The latter is large and has abundant light from three sides as well as the roof. It was planned with the idea of its being the main working center of the laboratory. In this room are the commoner materials and reagents for all ordinary work and the simpler forms of research. The preparation room is also intended to simplify as much as possible the routine work of the department. It is in charge of the technical assistant who prepares the sections for class work and keeps the stock solutions, reagents, and stains always in good condition. The room is provided with large unit tables, lockers for reagents and apparatus, thermostats, glass tubing and rodding, the still, and a large sink with numerous gas and water attachments, microtomes, museum jars for stock specimens, blast apparatus, vises, etc. Acid corrosions are made on extension shelves just outside of the windows, which do very well in lieu of a hood. There is also a large scale stand provided with coarse and fine balances.

The research rooms are occupied by individual members of the staff, and have, besides the usual water and gas supply, the equipments which the several members require for their own special work.

Histological Laboratory.

The histological laboratory is situated on the second floor, and was made by tearing down two partitions and converting three rooms into one. The room faces the north and abun-

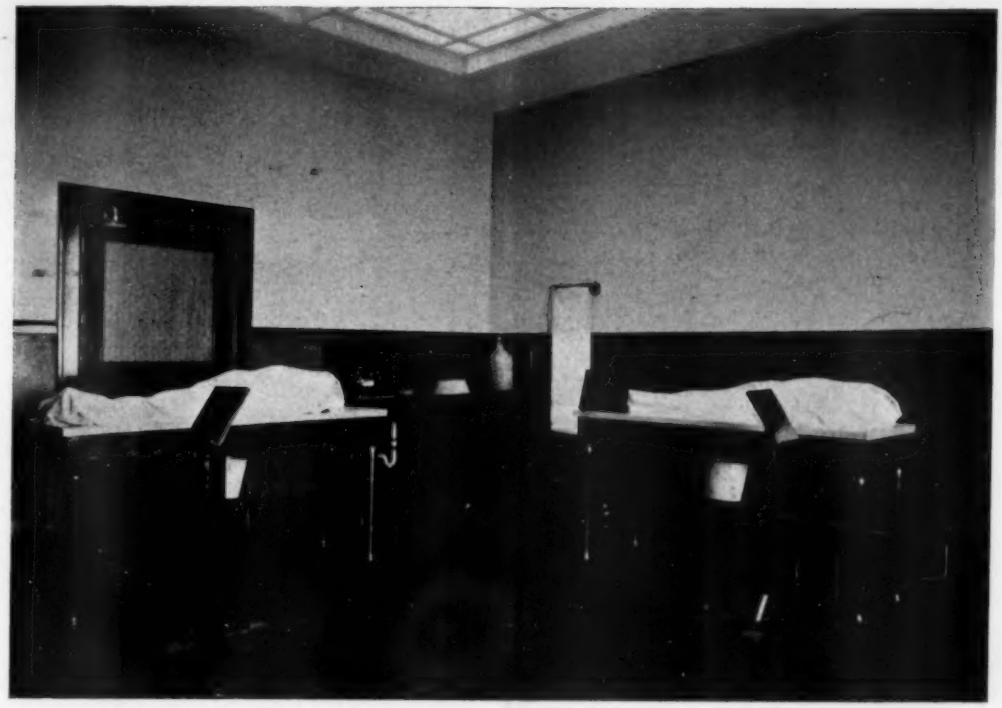


FIG. 2.—DISSECTING ROOM.

FIG. 3.—MODEL ROOM.

FIG. 5.—EMBALMING ROOM.

FIG. 6.—STORAGE TANKS AND ELEVATOR.

FIG. 7.—PREPARATION ROOM.

FIG. 8.—PRIVATE ROOM.

FIG. 10.—HISTOLOGICAL LABORATORY.

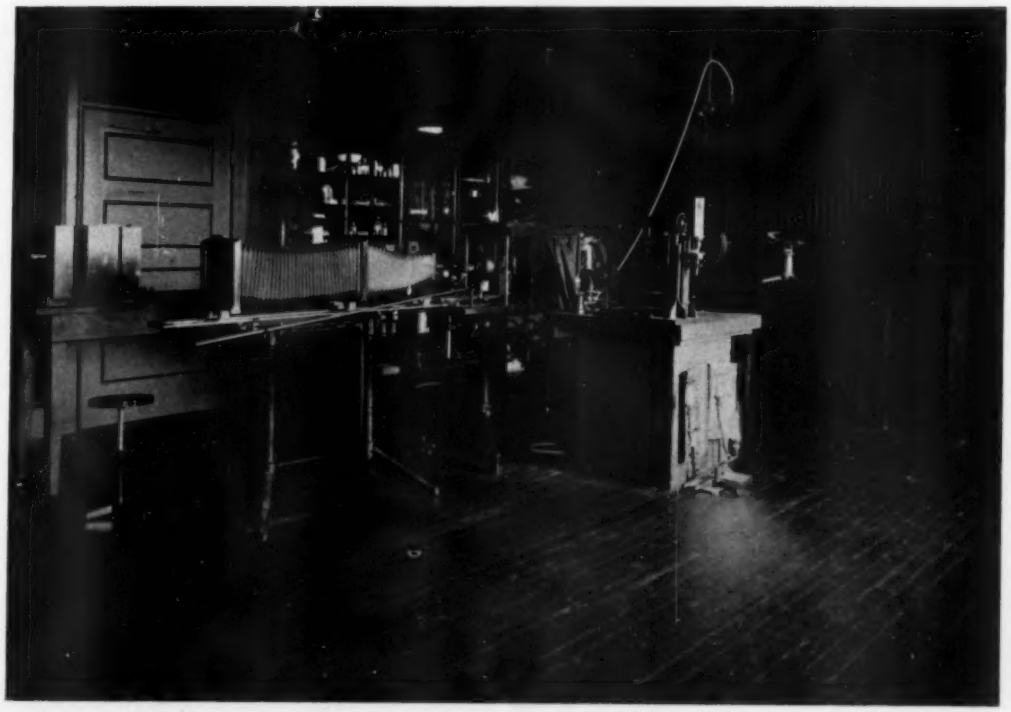


FIG. 12.—PHOTOGRAPHIC ROOM.

dant light was obtained by cutting two extra windows in the alcove. Students are seated either at wall-shelving or at long tables. The room has a capacity for fifty students at one time. There are two large sinks, a large paraffine oven with apartments for each member of the class. On the opposite side of the hall is a small room used for the storage of charts and microscopes. Each student is provided with a wall locker to which he carries a key. This locker contains his microscope, reagents and working equipment; a small wooden tray with holes that exactly fit the reagent bottles makes it easy for him to remove his reagents from the locker to the desk. Each locker outfit contains the simpler reagents and stains, while those that are only used occasionally are kept on the shelves above the sinks. The microscope outfit consists of a Leitz 1-A stand, with the 1, 3, 5 and $\frac{1}{12}$ objectives and the 0, 1, 3 and 4 oculars. Each student has, as well, a dissecting microscope for teasing purposes and low power work. The general equipment of the room consists of a stereoscopic microscope for demonstration purposes, microtomes for both paraffin and celloidin sections and a well-stocked cabinet. Most of the histological models are kept in the general model room. We have used bromide enlargements for our charts in microscopic anatomy. These are made from plates or figures from the literature illustrating the objects which it is desirable to show. They are very clear and are much cheaper than charts made by an artist.

PROJECTION ROOM.

The projection room is in the basement where the inconvenience of its situation is compensated for by the existence of brick piers erected independently of the building. These facilitate the making of photographs without the occasional annoying tremor caused by passing tram-cars. The walls and ceiling of the projection room are black, while the windows are protected with two sets of opaque curtains which entirely exclude the light when the room is used for projection. The room is equipped with a complete Zeiss microphotographic apparatus, consisting of bellows, plate-holder, microscope, condensers, filters, stand, etc., etc. The Zeiss apparatus is the property of the Department of Pathology and is used by both departments in common. Owing to the fact that there is no electric current in the building we were at first forced to use a cluster of Welsbach lights for microphotographic work. And while fairly successful pictures could be taken with this illumination, they were not wholly satisfactory, as the peripheral illumination through the higher powers of the microscope was vague. More recently we have employed a 3-burner acetylene lamp. With this light, we succeed in obtaining clear pictures with high magnifications. Successful projections up to 100 diameters can also be obtained by its use. The acetylene generators are now manufactured so they are safely, cheaply, and easily operated. Besides the Zeiss apparatus there is a large 8 x 10 copying camera, fitted with a 5-foot draw and bellows. This is equipped with a Zeiss protar lens. There is also a small Zeiss camera, 5 x 7, with a complete series of lenses for various grades of minor work.

Adjacent to the projection room is the dark-room, provided with a maze-doorway, by means of which it is possible to enter and leave the dark-room at will without closing a door. The light for the dark-room is situated in the projection room, thus it is easy to keep the former cool. A light-tight ventilator has also been arranged in the transom of the door in the dark-room, giving with the maze-entrance a constant current of air. It is possible, therefore, when occasion requires, for this room to be in use six or eight hours a day without having the air become either close or oppressive. I have tested the dark-room by leaving half a plate exposed for ten minutes in the doorway, while the other half was developed immediately for comparison. At the expiration of the time stated, absolutely no fogging was observed in the half of the plate used for the test.

UNIT SYSTEM OF FURNITURE.

As far as possible, the laboratory is furnished throughout on the unit system. Wall cases, museum cases, dissecting tables, laboratory tables, operating tables, wall shelving, sinks, book-stands, animal cages, etc., are all constructed on a unit system, making the rearrangement of the laboratory furnishings easy and practical. The furniture is stained a cherry red, while the table tops, sink tops, etc., are all stained with anilin black. Although the preparation of furniture by this latter method is rather tedious, the results amply justify the extra expenditure of energy. They are a dead black in color, are not acted upon by acids, alkalies, alcohols or any of the reagents used in ordinary anatomical work. After this treatment the furniture always looks well, and is easily kept clean. The process is so simple that an experienced painter is unnecessary, as any janitor can prepare the woodwork by this method. Three solutions are necessary:

Solution No. 1.	cc.
Anilin Oil	1.5
HCl	1.5-1.75
Water	1000

There should be sufficient HCl added to make the solution slightly acid. It is shaken until the oil globules no longer float on the surface, which occurs when the solution is slightly acid.

Solution No. 2.	cc.
Sodium Chlorate	100
Copper Sulphate	100
Water	1600
Solution No. 3.	**cc.**
Chromic Acid	5
Water	100

Paint with solutions No. 1 and No. 2 alternately three or four times, allowing each successive coat to dry thoroughly. One or two coats of solution No. 3 will then turn the wood perfectly black. After the surface is entirely dry, it may be rubbed down with boiled linseed oil or better with a 5% solution of paraffin in benzine. If the paraffin solidifies or crystallizes out, the surface of the table may be warmed with a Bunsen burner and the melted paraffin rubbed into the wood.

ANATOMICAL MATERIAL—ITS COLLECTION AND ITS PRESERVATION AT THE JOHNS HOPKINS ANATOMICAL LABORATORY.

By Franklin P. Mall.

In 1893 when the Medical Department of the Johns Hopkins University was opened, it was announced that the course in gross anatomy would be largely practical and that the work would begin on November 15. At the beginning of the session, in October, it was found that no cadavers were on hand, nor were the chances in favor of obtaining them good, for during the previous year but 49 subjects came through the regular channels, to supply the some 1200 students in the different medical schools of Baltimore. The problem now changed from teaching anatomy to obtaining cadavers for a new school, and only complicated the situation by adding more students to a number already far too large to be supplied. I soon learned that during the fall of the year the demand for cadavers by the seven schools was far greater than the State supply and that the additional irregular subjects did not ease the situation very much.

Several years before, a case of burking, followed by a scandal, aroused public opinion sufficiently to enable the Legislature to pass a law regulating dissection, after the bill had been introduced a second time and pushed with great vigor. This law, unfortunately, is a broad compromise, one which will not compel the leading officials to deliver the bodies of the unclaimed dead to the Anatomical Board, nor does it make it a legal offense to remove a corpse from the Public Cemetery. So in order to become operative in the direction in which the law was intended, *i. e.*, to give the bodies of paupers to the medical schools for dissection and thereby to prevent trafficking in them, it is necessary to have the good-will of the Health Commissioner and a strong Anatomical Board. At first a few bodies were delivered to the Anatomical Board but, as a rule, the pauper dead were claimed and buried at the expense of the city, or if "unclaimed" were also often buried by the city because it was difficult to determine whether the deceased had been a resident of the State for a year prior to his death. So by this interpretation of the law the Health Commissioner saw his way clear to send 49 cadavers to the Anatomical Board during the college year 1892-93.

During October, while waiting for dissecting material, I experimented upon dogs with all kinds of embalming fluids in order to have the best possible method for cadavers when obtained. I may add that during the six weeks these experiments were being made the bodies of all the dogs putrefied with the exception of those embalmed with carbolic acid. At this time the weather was unusually hot, even for Baltimore, and I made a sufficiently large number of experiments to decide in favor of a carbolic acid mixture as the best embalming fluid. This experience proved to be valuable, for we have ever since been able to embalm our subjects well and in turn the method has spread to many of the medical schools of America.

We were to begin to dissect on November 15, and before the date arrived the students began to worry, for they knew we had no subjects, and they also knew that they were not to be obtained. I myself felt very much the same in case we depended upon the State to send cadavers, and all preparations were made to go to larger cities for aid, which is easily obtained with a large purse. While these preparations were being made we postponed work until the 16th, and then the 17th, when, late in the evening, a subject was left in the basement. The next day one came from the State, and a few days later another appeared in the basement. This made us safe until Christmas, or until Easter, provided we dissected carefully and preserved the specimens well.

Towards Christmas, when all of the dissecting-rooms of Baltimore were under way, it was found that cadavers were more abundant and we did not fail to take what came, embalm them well with carbolic acid and place them in a large ice box which had been constructed in the meantime. By spring the box, which was built to hold five cadavers, had in it twenty and the further supply was not taken.

By this time it became apparent that in future it would be well to have an abundance of subjects on hand, and during the second year of the Medical Department an Anatomical Laboratory was built in which was placed an ice machine with a cold-storage vault large enough to hold 60 subjects. During the summer just 50 subjects were received, which together with 8 on hand nearly filled the vault. We also found that it was much cheaper to operate an ice machine than it cost to keep the large ice box filled with ice during the previous summer.

Shortly after the cold-storage apparatus was in operation the Anatomical Board proposed that all the subjects received by it during the summer should be stored in the Anatomical Laboratory. Heretofore these had been buried and were just so much loss to the Board. The Table on the following page shows in a measure the advantages of this arrangement by the gradual increase in the number of cadavers from year to year. I gather from the records of the Board that the total number of adult subjects delivered by the State have averaged 300 a year during the past five years, thus multiplying our supply sixfold, since we receive and preserve every subject. Furthermore, there are the bodies of about 300 infants which are also used extensively, making 600 in all, which would be enough to supply the demand were there not a gradual increase of the total number of medical students in Baltimore from year to year.

TABLE GIVING THE RACE AND SEX OF THE CADAVERS ARRANGED IN HUNDREDS.

The dates of the reception of each hundredth subject, the number of autopsies, the source of the cadavers, and the number of bodies returned to friends are also given. The first cadaver was received on Nov. 17, 1896.

Number in hundreds.	Date of Reception of each hundredth Cadaver.	Race not given.		Negro.		European.		Autopsy.	Number received from "outside sources."	Number returned to friends.
		Male.	Female.	Male.	Female.	Male.	Female.			
100	Oct. 12, '95	41	11	30	16	9	3	30	45	0
200	April 16, '97	3	2	42	21	25	7	25	27	2
300	Oct. 16, '97	3	0	40	21	32	4	43	50	0
400	May 26, '98	3	0	37	26	31	3	44	28	1
500	Oct. 10, '98	0	1	38	31	25	5	44	2	0
600	Mch. 18, '99	0	0	48	16	29	7	53	1	0
700	July 26, '99	3	8	43	21	21	4	34	0	1
800	July 13, '00	0	10	43	19	26	2	31	0	0
900	Feb. 27, '01	1	0	36	26	28	8	33	0	3
1000	June 10, '01	1	0	54	18	23	4	49	0	4
1100	Oct. 31, '01	0	0	50	21	24	5	27	0	2
1200	July 3, '02	0	0	42	31	24	3	41	0	5
1300	April 6, '03	0	0	42	21	27	10	43	0	10
1400	Nov. 9, '03	1	1	47	25	23	3	41	0	3
1500	April 12, '04	0	0	44	27	25	4	30	0	6
1600	Aug. 13, '04	0	0	44	22	27	7	33	0	5
1641	Oct. 1, '04	0	0	17	8	13	3	13	0	2

In 1897 a new Health Commissioner, Dr. Jones, was appointed and his order was "that all bodies should be turned over to the Anatomical Board for disposal, and if they were not wanted should be buried in the Public Cemetery." Although the cadavers received at the Johns Hopkins are not the total number received by the Anatomical Board during the year, they are in a measure a proportion of the whole, for they include a certain per cent of those collected during the winter and all of those of the summer. During the four years preceding Dr. Jones' appointment the Anatomical Board sent to the Johns Hopkins for storage an average of 44 subjects, while during the time he was Commissioner of Health the average rose to 185, which has been maintained ever since. Shortly after Dr. Jones' appointment I was elected Chairman of the Anatomical Board (October, 1898), and immediately took steps to complete the work Dr. Jones had begun. Orders were issued to the medical schools not to accept cadavers from outside sources, for there was an abundance of them on hand, and a form of receipt was introduced by which a cadaver could be traced had it gone astray. So since that time no cadavers have been procured from outside sources for dissection, for the "go-between" has had neither stock nor buyer, for all of the unclaimed dead go directly to the Anatomical Board.

The receipt enabled the Anatomical Board to keep the accounts up to date from a business standpoint. Before this there was no great haste in rendering bills nor in paying them, but from now on accounts were balanced once a month and any discrepancy could easily be corrected, for the details were still fresh in mind. Since the trafficking in dead bodies was effectually broken up in Baltimore, the one source of danger, *i. e.* sending bodies beyond the borders of the State, had to be watched and it was this receipt which proved to be of value in finding and convicting an offender several years later (see Devine case). From this time on the receipts became official and are stored in the Health Department.

The business side of the Board is now in good running order, being in the hands of a secretary appointed by the Chairman of the Board, who in turn is elected annually by the Board. When I became Chairman, Dr. Warfield, my predecessor in office, handed over to me bills for nearly $1000, one-half of which had been paid in advance by him. I immediately sent out bills and thereafter made a settlement once a month, collecting from the schools receiving them $4 for each whole cadaver and $2 for each autopsy. At the end of the first year we had no debts and $123 in the treasury, and a year later $673, which has been increasing in amount ever since.

We are now obtaining all of the cadavers within the scope of the law, are dividing them according to legal requirements, have our treasury in good condition, are watching those who desire to cut into our supply (a certain type of burial society), and cooperate with the Health Department. Now, instead of having a column in our records of which we can give no account, we can account for every cadaver and often bodies are temporarily stored with us to be returned to friends when so ordered by the Commissioner of Health. During 1903 fifteen such bodies were returned, and during 1902, one which we had had in storage for eight months.

It is evident from what has been said above that the collection of cadavers for dissection was greatly facilitated when they were carefully embalmed and stored, for by so doing they could be collected during the summer, or whenever in excess, and kept until there was a demand for them. From a small beginning with an ice box holding five cadavers, a vault was built, and shelved to hold sixty cadavers. Later, the shelves were removed and the bodies were stacked, which proved to be better for the bodies, at the same time increasing the capacity of the vault six-fold. During these ten years we have had considerable experience in operating a small ice machine, in aiding to construct new plants elsewhere and in the different methods of embalming cadavers with carbolic acid. The problem presents different aspects according to the intelligence of the embalmer and the number of subjects to be embalmed each week. If there is a small number, say 50 a year, it is a question in my mind whether it is economical in time and expense to preserve cadavers by means of cold-storage. If the number per year is over 100, *i. e.*, at least 50 to be stored constantly, refrigeration has decided advantages.

At first the bodies were injected with 2 liters of a solution of equal parts of carbolic acid, glycerine and alcohol. I constantly came back to this solution, for it is easily handled and but small quantities are needed. But it is found that with so small a quantity but little of it reaches the feet, while most of it lodges in the viscera. So the quantity was gradually increased until from 4 to 6 liters were used, which means about 3% of carbolic acid to the body weight. Even with this quantity enough acid rarely reaches the feet, so it was necessary to change the method and inject the embalming fluid into the legs. At first but one femoral artery was used,

but in such cases it was difficult to force enough of the fluid into the arteries of the foot of the opposite leg. So, thereafter, cannulæ were introduced into the femoral arteries of both legs, and the legs were first injected and then the body. In making these injections a constant pressure is used, from 150 to 200 mm. Hg., for this is much more certain than the irregular pressure given by a syringe.[1] In cadavers preserved in this way all parts are well embalmed, provided clots of blood have not blocked any of the arteries. Most of the muscles are coagulated in cadavers prepared as described above, and this is desirable in case they are to remain in the dissecting-room for a long time. If less acid is used the muscles retain their normal color and consistency, but the preparation becomes infected easily and decomposes in warm weather. Furthermore, the moisture required to keep the preparations from drying hastens the decomposition.

It was also found that the hands, feet and face dried easily in the dissecting-room, and especially in cold-storage, and to prevent this the body was carefully wrapped immediately after the embalming process was ended. First the hands, feet and face were smeared with vaseline and wrapped with bandages of tissue paper which is ordered from the mills in rolls 5 inches wide and 3 inches in diameter. Then these bandages and the rest of the body were smeared with vaseline and the whole carefully wrapped with bandages of cheese-cloth about a foot wide. It is well to wrap the legs and arms separately in order that they may be exposed easily for dissection, the rest of the body remaining wrapped, for the covering is an additional protection in the dissecting-room. Such bodies may be retained in cold-storage indefinitely without drying, although the thorax and abdomen gradually lose much of their moisture.

Immediately after embalming and before the body is wrapped the arteries are injected with pigment. For this purpose it is desired to have granules which fill the finer arteries but do not enter the capillaries. The arteries of the first 200 cadavers were filled with red-lead and plaster-of-Paris, but it was found that the injection was often incomplete and in addition the action of the carbolic acid caused the color of the lead to turn black. Experiments were then made with all kinds of granules and fluids and it was soon found that granules of ultramarine blue mixed with shellac and alcohol proved to be the best. The granules are cheap, are just small enough to pass to the finest arteries; the solution is injected cold, and can be kept in stock constantly. It sets in the course of a month which is no disadvantage, for we rarely dissect fresh bodies. No attempt is made to distend the larger arteries, but it is desired to fill the many smaller arteries, as those of the periosteum and of the skin. Keiller accomplishes the same with chrome-yellow and gelatin but his cadavers are embalmed with a formalin solution which causes the gelatin to become insoluble and tough. Apparently his results and ours are about the same.

About 1000 cadavers were embalmed by injecting each with 5 or 6 liters of a 33% solution of carbolic acid as described above. The vessels were colored with the ultramarine shellac solution. They were then vaselined and wrapped and kept in cold-storage until needed. But it was found that occasionally an extremity was not well embalmed and frequently the epidermis would macerate and peel off with a subsequent putrefaction of the skin. Often it would soften and peel off, especially from the hands and feet after they had been kept wrapped for a long time in the dissecting-room. To obviate this the parts had to be watched and in case the artery was found plugged it was picked up and injected a second time. The skin was also treated with a solution of glycerine, carbolic acid and water and in extreme cases with the original embalming fluid. This, however, was found to be inconvenient and unsatisfactory, so we began systematically to try and remedy the defect. Struthers[2] had already met this difficulty by painting the cadavers with carbolic acid and glycerine (1 to 8) a number of times, say 3 or 4, to embalm the skin from without, or in other instances by injecting the same solution hypodermically. This is inconvenient when many cadavers are to be painted, especially when but a few of them are to go to one's own dissecting-room, so I began by immersing the whole body in different solutions of carbolic acid after the arteries had been injected. It was noted above that in embalming a cadaver it is best to inject exactly 3% of pure carbolic acid to the weight of the cadaver in order to obtain the best results, and upon experimentation I found that the same strength gave the best results in a tank. A 4% solution is too strong and in a 2% solution the skin macerates and the epidermis falls off. Dr. Bardeen also obtained the same results with embryo pigs which are used in great number in our laboratory, and recently Keiller has confirmed Struthers' results with hypodermic injections. Keiller, however, uses large quantities of an aqueous solution of carbolic acid and injects it until the body is very œdematous. In all cases the principle and the results are the same.

The experiments with the vat were frequently made upon the subjects between Nos. 900 and 1300, at first upon single cadavers and later with 10 at a time. It was found that cadavers which were evenly embalmed, epidermis included, with a 3% solution of carbolic acid and wrapped with carbolized vaseline could be kept upon an open shelf in a warm room at Baltimore for at least 6 months and still be perfectly good for dissection. A cadaver prepared in this way cannot be detected from others by its quality or appearance. It should be possible to keep them indefinitely in an aseptic room with an atmosphere saturated with moisture. But to make the method easy two large tanks holding about 4000 liters each were constructed, which were half filled with a 3% solution of carbolic acid. Each holds about 15 cadavers. First, one was filled with cadavers that had been embalmed in the usual

[1] Professor Keiller (Phil. Med. Jour., Dec. 29, 1900) distributes the carbolic acid evenly by injecting a large quantity of aqueous solution into the carotid, and also hypodermically, until the whole skin is distended. His results are practically identical with ours, differing only in the per cent of acid to the bodyweight.

[2] Struthers, Edin. Med. Journ., Oct., 1890.

way, and then the other. All the cadavers are then taken from the first tank, vaselined and wrapped and placed in cold-storage. The water of the first tank has lost some of its carbolic acid which is to be replaced. An easy method to ascertain this loss is to determine how much carbolic acid 100 cc. of the filtered solution will take up and to compare it with the amount required to saturate 100 cc. of water. If at a given temperature it takes 4 cc. of the straw-colored carbolic acid to saturate 100 cc. of water and 2 cc. to saturate 100 cc. of the filtered fluid under test, then one per cent must be added to the tank to bring it back to a 3% solution. When the first tank is full of bodies the second is emptied, the bodies being wrapped and stored and the fluid of the tank strengthened. And so on. At the rate we receive cadavers they remain in these tanks from 3 to 6 weeks, long enough to allow the carbolic solution to penetrate them from 2 to 4 centimeters. I may add that we use the straw-colored carbolic acid (strength 92 to 97%) which is cheap and is as good for the vat and for the arteries as is the more expensive crystalline form.

Beginning 18 months ago (with No. 1300) each cadaver was embalmed with 6 liters of a 33% solution of carbolic acid, injected with about 2 liters of shellac alcohol and ultramarine blue, immersed in a 3% solution of carbolic acid for 3 to 6 weeks, vaselined and wrapped, and preserved indefinitely in cold-storage. At present we are constructing an underground vault to be carefully cemented with water-proof cement and large enough to hold 150 bodies. In case cadavers can be kept indefinitely in a 3% solution of carbolic acid, I see no reason why our cold-storage apparatus should be replaced when it is worn out.

It appears to me that carbolic acid is by all odds the best preservative for cadavers for dissection. It is easily injected and diffuses rapidly and extensively. So great is the power of diffusion that the heads of autopsy subjects, which are not injected, are preserved by the carbolic acid which diffuses from the trunk. It is also the best solution in which to keep cadavers. It is also antiseptic, so much so that I have never seen the slightest sign of an infected wound in our dissecting-room, and does not injure the instruments. It is not necessary to pay any attention to slight wounds for they heal more rapidly in the dissecting-room than elsewhere, when the bodies are embalmed with carbolic acid. Finally, it is inexpensive. A gallon of straw-colored acid costs but 40 cents, and half this amount is enough to preserve a cadaver for several years, and the other half will make enough 3% solution to immerse it.

Alcohol and glycerine are also excellent preservatives, and possibly more glycerine would improve the embalming fluid somewhat. It is especially valuable in keeping the dissection from drying too rapidly while the student is at work. However, in order to prevent drying the student swabs the dissection whenever necessary with a 10% solution of glycerine in alcohol (see Gerrish's Anatomy), with which he is supplied. By this method it seems to me that the glycerine reaches the right place, while when it is injected much of it is wasted. When the student leaves his work he covers the dissection with a dozen thicknesses of moist (not drenching-wet) cloths, and all is again covered with water-proof sheeting which is prepared by saturating domestic or duck with boiled linseed oil as recommended by Keiller.

When the subjects are ready to be stored each is marked with a special tag, which cannot be duplicated, and is delivered on the desk of the instructor in charge of the vault when the cadaver is sent out of the laboratory or to the dissecting-room. The first 1000 are marked A, the second 1000 B, and so on. Each body is also recorded in a book, which the janitor keeps, and upon a card, which is here reprinted, for the instructor in charge. Once a year an inventory is taken and the cards are stamped with the inventory date. Thus every precaution is taken to keep track of the bodies.

JOHNS HOPKINS UNIVERSITY

ANATOMICAL LABORATORY

No.....Name..... .....Age.....

Length.....Weight..... .....

Date of Death.....190 Cause of Death.....

Received..... 190

....

Transferred to.....

SEX	COLOR	AUTOPSY	QUALITY
Male Female	White Black Mulatto	Yes No	Fat Medium Lean

Injected with.....quarts of.....at.....inches pressure.

Arteries injected with..... .....at.....inches pressure.

Put in.....% Carbolic vat..... ...190

Transferred to Cold Storage.....190

Embalmed by..... .....

At first it was impossible for me to obtain easily the names and data of the bodies, but I had the color, sex and quality carefully recorded. These records often proved to be of value while making studies and in identifying bodies in case they were sought by friends. After No. 767 the names and ages are recorded. The cause of death is given after No. 901. The length and the weight of the body together with the intermediate color, mulatto, is recorded after No. 1448.

The Table on the following page gives a list of the cadavers which have been stored up to October 1, 1904. It shows how many bodies were used within the first year after they were received, within the second, and so on. The more recent subjects are all rated to October 1, 1904, so the 15th and 16th hundreds appear to have been used, while in reality most of them are still on hand. It will be noticed that under 400 a subject was kept for 5 years, and in the dissecting-room this cadaver proved to be as good as any of the fresher ones. A number were kept 4 years and in no case did the students suspect that they were dissecting subjects which we had had on hand so long. Under 500 a subject was kept 7 years and this we still have on hand. Generally, it is our aim to dissect cadavers which we have had on hand for two or three years, while the fresher cadavers are sent by request to other medical schools. Our experience demonstrates conclusively that cadavers preserved in cold-storage for several years are more satis-

factory for dissection than are fresh ones, and there is no reason why they cannot be preserved in this way indefinitely in case they are packed closely to prevent evaporation. This we now accomplish by stacking all of the old cadavers on one side of the vault with an air-space around the pile, and then the fresh cadavers are laid closely on a platform on the other side of the vault, and when this has frozen a second layer is placed over it, and so on. The wrapping prevents the subjects from freezing together firmly.

TABLE SHOWING HOW LONG THE CADAVERS WERE KEPT IN COLD STORAGE BEFORE BEING DISSECTED.

They are grouped in hundreds. The first column gives the number that were used during the first year. The records are carried to October 1, 1904.

Number of cadavers in hundreds.	1 year.	2 years.	3 years.	4 years.	5 years.	6 years.	7 yrs.
100	69	25	2	3	1	..	..
200	72	19	8	1	..	..	..
300	71	22	5	2	..	..	..
400	67	23	9	0	1	..	..
500	31	49	19	0	0	0	1
600	49	40	9	2	..	..	..
700	74	26	..	..	..	..	..
800	41	59	..	..	..	..	..
900	39	59	2	..	..	..	..
1000	29	61	9	1	..	..	..
1100	80	13	6	1	..	..	..
1200	76	19	5	..	..	..	..
1300	51	36	13	..	..	..	..
1400	27	73	..	..	..	..	..
1500	100	..	..	..	..	..	..
1600	100	..	..	..	..	..	..
1641	41	..	..	..	..	..	..

A Word Regarding Cold-storage.—The first cold-storage apparatus for the preservation of anatomical material was installed by Professor Huntington at Columbia University, about 1893. His apparatus was operated from a large central plant and was by no means inexpensive. Our vault was the second and was constructed early in 1895. The problem at the Johns Hopkins was different, for it was necessary to put in all of the machinery, which on account of the additional expense could not be operated during the night. In order to make this possible the brine tank was set up within the vault and from this the brine was pumped through pipes along the ceiling. When the machine was not in operation the large amount of cold brine within the vault was adequate to absorb much of the heat which entered, thereby keeping the temperature well below the freezing point. We found that we had planned so well that it was necessary to operate the machine but once or twice a week during the winter and but six hours a day during the hot summer to keep the temperature well below 32° F. all the time.[2] Had the surface of the brine tank been larger it would have been possible to keep the temperature of the vault below 32° without circulating the brine through pipes suspended from the ceiling. So at my suggestion a number of recent apparatuses have been constructed with three or four very narrow brine tanks set around the side of the vault, without any brine circulation. By this arrangement it is found that the temperature of the vault can be kept with ease below the freezing point. Vaults constructed in this way are to be found at the University of Pennsylvania, at Cornell University and at the University of Wisconsin. The vault at the University of Wisconsin is the most recent and was designed by Prof. Miller. It is built of porcelain brick, no wood being used in its insulation and all sides of the vault are lined with narrow brine tanks extending from the floor to the ceiling. Throughout it is a dry vault, which favors its insulation, so much so that during the hottest weather its temperature rises but 3° in 24 hours, with the ammonia turned off. As far as I can see it should last indefinitely, for the compressed ammonia is supplied from a distant plant, so there is no machinery to get out of order. Under these conditions cold-storage vaults are certainly much more desirable for the preservation of cadavers than carbolic acid vats.

[2] See Mall, Arch. Anz. XI and Johns Hopkins Hospital Bulletin, 1896.

THE DEVELOPMENT OF GRAVE ROBBING IN ENGLAND.[1]

By G. Canby Robinson, M. D.,

Pennsylvania Hospital.

In England, by Act of Parliament in 1540, four executed criminals were given yearly to the Barber-Surgeons for dissection, and twenty-five years later, Queen Elizabeth granted the bodies of four felons executed in Middlesex to the College of Physicians of London "that the president or other persons appointed by the college might, observing all decent respect for human flesh, dissect the same." In 1663 Charles II increased the number of criminals to be annually dissected to six, and in 1752, Act of 22, George II required dissection or hanging in chains of bodies of all executed murderers in order that "some further Terror and peculiar mark of Infamy might be added to the Punishment of Death." This Act, although no doubt an aid to the advancement of anatomy for the time being, produced in England a deep-rooted association of the dissection of the body after death with some serious crimes committed before death, and so strengthened the public feeling against the dissection of unclaimed pauper dead. This was a potent factor in hindering the passage of an anatomy act in England.

[1] Extracts from a paper read before the Johns Hopkins Hospital Historical Club, October 10, 1904.

Let us now consider the growth of the Anatomical Schools in London and Edinburgh, and trace there the fight between a deep-rooted instinct to protect the dead and the scientific spirit which demanded subjects for dissection.

The teaching of anatomy in England, which was first attempted in a well ordered manner a short time before 1600, was conducted entirely by a few corporate bodies of which the Company of Barber-Surgeons and the College of Physicians of London were the most important. The bodies of criminals provided by law were used. These Public Anatomies, as they were called, when held by the Company of Barber-Surgeons, took place in the Hall of the Company, and were conducted with much pomp and ceremony. Attendance upon them was compulsory to the members of the Company, they being fined when absent. The Public Anatomies were held usually four times a year, and three bodies were dissected each time, one to show the muscles, one to show the bones, and one to show the viscera. Private anatomies were forbidden by the Company. In those days when executions were much more frequent than to-day, and when the method of teaching was such that a few bodies sufficed, the law provided a sufficient number. Even at this time, however, certain broad-minded, thoughtful people, having in mind the great benefits to mankind to be derived from a widespread knowledge of anatomy, bequeathed their bodies for dissection, in order to aid in the spread of this knowledge, and to abate the public feeling against dissection.

In the seventeenth century, under the influence of such teachers as William Harvey, interest in anatomy began to increase very much, and gradually more men arose who, like Vesalius, wanted to investigate things for themselves. And so we find that in the first part of the eighteenth century, about 1715, private schools of anatomy began to be established in London. This meant of course that subjects for dissection had to be provided by other than legal means, and here was the commencement of the systematic robbing of graves.

The business of providing the anatomical schools with subjects by grave robbing gradually became a well organized trade in London. The character of the men engaged in this most repulsive and dreadful occupation, can be well imagined. The century ending in 1832, when sufficient material was provided in England by the Warburton Anatomy Act, presents indeed a gruesome page in the history of anatomy. The master pen of Robert Louis Stevenson has described this night prowling grave robber in words that help us to realize what a depraved creature he must have been. "The Resurrection Man—to use a by-name of the period—was not to be deterred by any of the sanctities of customary piety. It was part of his trade to despise and desecrate the scrolls and trumpets of old tombs, the paths worn by the feet of worshippers and mourners, and the offerings and the inscriptions of bereaved affection. To rustic neighborhoods, where love is more than commonly tenacious, and where some bonds of blood or fellowship unite the entire society of a parish, the body-snatcher, far from being repelled by natural respect, was attracted by the ease and safety of the task. To bodies that had been laid in earth, in joyful expectation of a far different awakening, there came that hasty, lamp-lit, terror-haunted resurrection of the spade and mattock. The coffin was forced, cerements torn, and the melancholy relics, clad in sackcloth, after being rattled for hours on moonless by-ways, were at length exposed to uttermost indignities before a class of gaping boys."

The deeds of one of these resurrection men has come down to us from his own pen in the form of a diary. It was published in 1896 by Bailey, Librarian of the Royal College of Surgeons of London, and the book contains besides the diary which gives it its title, "The Diary of a Resurrectionist," an account of the resurrection men in London and a short history of the passing of the Anatomy Act. It is from this book that much of the following material has been gathered.

After several anatomical schools had been established in London, there was much rivalry between them for material. This gave the gangs of body-snatchers an independence of which they naturally took advantage, and a great amount of tact was sometimes necessary to keep them in good humor. When as dawn of day was approaching, these ghouls would stealthily knock at the lonely back entrance which admitted them with their gruesome burdens to the anatomical school, the rule was to pay cash and ask no questions, and with as few words as possible to let them hurry indoors while the cover of night could conceal their muddy clothes and grimy hands, the marks of their profession.

The "Resurrection man" was in a position to do much harm to an unpopular school, and he had many ways of doing it. It is told that one teacher, Mr. Brookes, whose school had incurred the displeasure of the resurrectionists, awoke one morning to find a partially decomposed human body on his door steps, put there by these disgruntled robbers to arouse public indignation against him. On another occasion a subject for dissection was delivered to Mr. Brookes in a sack. Upon investigation the subject was found to be alive, and was probably so introduced into his house for purposes of robbery.

The means used for protecting the graves against the stealing of their contents were numerous. High walls were built on which loose stones were placed, watch towers, as may be seen in the cemetery outside of Dublin, were erected, and "mort safes" or graves covered by strong iron gratings, were used. One enterprising manufacturer published a long advertisement in the daily paper, extolling the merits of Lillie's Iron Coffin. The advertisement commenced by saying that "Hundreds of human bodies will be torn from their graves this season to supply the demand of the anatomical schools of London and Edinburgh." At Crail a house was erected in 1826 in which bodies were put to remain until partly decomposed and so useless for anatomy, and then buried.

This trade in human corpses was not carried on entirely by men, for we find that several of its tricks could be properly performed only by women. A spring gun was sometimes put over a new grave. The sorrowing mother or bereaved widow would appear a few hours after the funeral, and would go to the grave to let fall her mournful tears upon the freshly turned up mound, and incidentally to cut the wires leading to

the spring gun. Then too a woman was especially useful for going to an anatomical school, and there with much grief to find her child or husband, whose body she had heard had been stolen. Nearly overcome by her great sorrow she would have the body removed, to be carried to the next anatomical school and resold, the gang thus gaining two prices for it.

Bodies did not always reach the grave awaiting them, but were sometimes stolen before burial and were sometimes sold by the grave diggers themselves.

As ordinary means of protecting the graves often failed, and as the custodians of the burying grounds could usually in those days be bribed or made intoxicated, a private watch was sometimes instituted over a new-made grave. Between the watchers and the gang of grave robbers, violent fights sometimes took place. An account of such a fight is to be found in an Irish newspaper of 1830, entitled "Desperate Engagement with Body-Snatchers." "The remains of the late Edward Barrett, Esq., having been interred in Glasnervin Churchyard on the 27th of last month—(January), persons were appointed to remain in the churchyard all night, to protect the corpse from the 'sack-'em-up gentlemen,' and it seems the precaution was not unnecessary, for on Saturday night last, some of the gentry made their appearance, but soon decamped on finding they were likely to be opposed. Nothing daunted, however, they returned on Tuesday morning with augmented force, and well armed. About ten minutes after two o'clock three or four of them were observed standing on the wall of the churchyard, while several others were endeavoring to get on it also. The party in the churchyard warned them off, and were replied to by a discharge from firearms. This brought on a general engagement, the 'sack-'em-up' gentlemen fired from behind the churchyard wall, by which they were defended, while their opponents on the watch fired from behind the tomb stones. Upwards of 58 to 60 shots were fired. One of the assailants was shot, he was seen to fall; his body was carried off by his companion. Some of them are supposed to have been severely wounded as a great quantity of blood was observed outside the churchyard wall, notwithstanding the ground was covered with snow. During the firing, which continued upwards of a quarter of an hour, the church bell was rung by one of the watchmen, which, with the discharge from the fire-arms, collected several of the towns-people and the police to the spot, several of the former, notwithstanding the severity of the weather, in nearly a state of nakedness; but the assailants were by this time defeated and effected their retreat."

So we see that this trade, as one would expect, was not without its perils. Conflicts in the cemeteries over bodies were not uncommon, but the fights were usually between two rival parties of resurrection men, and the rivalry between the different gangs that haunted the various burying grounds was intense. In fact it was largely owing to information that these men gave to the police against their competitors that body-snatching reached such great publicity.

The amount of money that could be made in this nefarious trade was an inducement for men to forsake honest but poor-paying trades for it. A body-snatcher testified before the Anatomy Committee of the House of Parliament that during the dissecting season of 1809 and 1810 his gang of six or seven men had disposed of over 300 bodies at the average price of £4, 4s., or about $20.00, thus reaping an income of about $6000.00, or nearly a thousand dollars apiece. The teeth of the subjects were generally sold to dentists, from which source an extra sum was derived.

When anatomical material could not be obtained in plenty by robbing the graves alone, worse crimes were added, in order that the ghouls might have their money. The state of affairs into which this business had grown may be shown by a brief glance at conditions in Edinburgh in the first part of the nineteenth century.

Under the Monros, father, son and grandson, who had held successively the University Chair of Anatomy from 1720 to 1846, the School of Edinburgh rose to first rank. Schools of anatomy outside the University, where extramural teaching was done, were established. One of the most successful of these was conducted by Dr. Robert Knox, who had, during 1828 and 1829, a class of 505 students. The demand for subjects in Edinburgh was of course very great. Bodies brought from £10 to £20 each, and were even imported from England, Ireland and France.

In 1828 Edinburgh was stirred to its foundations by a realization of the extent to which the traffic in human corpses had grown. This realization was brought about by the facts made public in connection with the famous Burke case, an account of which I quote from Hartwell.

"On the second of November, 1828, it was noised about in Edinburgh that a woman had been murdered on All Hallow Eve for the sake of her body, which was found in the dissecting room of Dr. Knox. In the investigation which followed, it was discovered that William Hare, the keeper of a low lodging house in the West Port, and one of his lodgers, William Burke, had within less than a year, committed sixteen murders, and disposed of the bodies of their victims to the teachers of anatomy. The "Burke" method was to suffocate the victim, already dead drunk. Throttling was not resorted to; the nose and mouth were kept tightly closed, and smothering was soon effected. It was impossible to connect Knox with these villains in any way, except as a receiver of stolen goods for the benefit of the public. Hare turned State's evidence, but Burke was found guilty, hanged and dissected. His skeleton adorns the Anatomical Museum of the University of Edinburgh."

Horrible as this crime was, it was not the last to be attached to and to besmirch the name of anatomy in Great Britain, as London was to see another crime almost as dreadful. Another atrocity was needed to arouse the law makers of England to the realization that some efficient means of protecting the graves must be provided. A crime came to light in November, 1831, in London, which created a sensation, Bailey says, equal to that raised in Scotland by the atrocities of Burke and Hare.

Three men, Bishop, Williams alias Head, and May, accom-

panied by a porter, brought a subject for dissection, a boy of 14, to King's College. The appearance of the body aroused the suspicion of Hill, the dissecting-room porter, and apprehending foul play, he notified Mr. Partridge, the demonstrator of anatomy. The porter's suspicions were confirmed by Mr. Partridge. He produced a fifty pound note and said he could not pay them until it had been changed. In the meantime he communicated with the police, who took the men into custody.

In December, 1831, the three men were found guilty of murder and sentenced to death.

The body proved to be that of an Italian boy who made a living by showing white mice. He had been enticed, so the men confessed, into their dwelling in Nova Scotia Gardens, where he was drugged with opium, and then let down into a well until suffocated. They also confessed to the murder of a woman named Fanny Pigburn, and a boy whose name was supposed to be Cunningham. Both of these bodies they sold for dissection.

Fifty thousand copies of the Dispatch containing their confession were sold, and at the execution many persons were injured in the crowd.

The English public were deeply stirred by these crimes. Something had to be done to protect the graves, and to do away with the gruesome traffic that had grown to such a point that the villains engaged in it did not stop short of murder to obtain their merchandise. Various legislative schemes were proposed and one bill providing anatomical material had passed the House of Commons to be defeated in the House of Lords. In August, 1832, however, the famous Warburton Anatomy Act finally passed through both Houses of Parliament to become a law. This Act provided that a license for the study of anatomy should be issued to proper persons and that the bodies of unclaimed pauper dead might be turned over to those holding licenses for anatomical purposes. Burial was required of all bodies by anatomists six weeks after they were received. It was no longer a misdemeanor for one holding a license to have a body in his possession, and there was a very important clause repealing the law, requiring dissection of all executed criminals. Inspectors, one for each country, England, Ireland and Scotland, were appointed by it. This law was a great success and Bailey says of it, "after the passing of the Act the resurrection man, as such, drops out of history; his occupation was gone, and one of the most nefarious trades that the world has ever seen came completely to an end."

We cannot speak at this time of the methods used for obtaining anatomical material in this country, where the settling of the problem is more complex, as a separate law is necessary for each State. It is pleasant, however, to briefly recall the fact that, after a fight of some years, Massachusetts, our most cultured State, passed a liberal anatomy act, legalizing the dissection of unclaimed pauper dead, in February, 1831, a year and a half before the passage of the Warburton Anatomy Act in England, and was the first English speaking community to have such a law.

Although it cannot be denied that body-snatching still exists to a slight extent in this country, yet most of the States have good anatomical laws, which efficiently provide material for dissection. As the robbing of graves passes out of existence, there disappears also the dread and horror with which the public has regarded for hundreds of years the study of anatomy, as the public has learned to appreciate the great importance of sound anatomical training as a firm foundation for all branches of scientific medicine.

ON FLECHSIG'S INVESTIGATIONS ON THE BRAIN.[1]

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The first report made to the Central Committee for the Investigation of the Brain consists of a paper by Paul Flechsig which marks an epoch in the history of the nervous system. This work lays the foundation of our knowledge of the paths in the brain and their relation to the basal ganglia. The work represents the study of serial sections of 56 human brains between the stage when myelinization first begins, four months before birth, and the time when every portion of the cortex shows some medullated fibers and the main paths are laid down, namely, four months after birth. This entire period represents eight months. Through the study of these brains Flechsig divides the cortex into 36 areas, of which the first 12 are myelinized before birth and the rest after birth. The sequence of the numbers represents the time of medullation, and as will be seen the time of birth is not a fundamental division. In general the study of these different zones shows that the first areas in the cortex to become medullated are primary sensory areas representing smell, touch and muscle sense, sight, hearing and taste. The next group of centers to become medullated have at first only fibers within themselves, that is, neither projection fibers nor association bands, so Flechsig calls them automatic centers of unknown meaning. The rest of the areas have association bands and it is most interesting that the earlier zones of this group develop as a marginal zone around the primary sensory areas and first

[1] **Flechsig: Einige Bemerkungen über die Untersuchungsmethoden der Grosshirnrinde insbesondere des Menschen. Dem Centralkomite für Hirnforschung vorgelegt. Berichten der mathematisch-physischen Klasse der Königl. Sächs. Gesellschaft der Wissenschaften zu Leipzig, Jan. 11, 1904.**

receive short fibers from them. They are undoubtedly connected with the sensory areas in function. The last three zones develop long association bands first and are the great association centers. This will be summed up in the following classification.

I. Primary areas.
  1. Areas with primary sensory projection fibers. 1, 2, 4, 5, 6, 7, 8, 15.
  2. Areas without primary projection fibers; mostly automatic unknown areas. 3, 9, 10, 11, 12, 13.

II. Association areas.
  1. Intermediate or border zones, with short fibers. 14, 16-33.
  2. Terminal or central zones, with long fibers. 34, 35-36.

The following is the list of zones, which is to be compared with the figures:

AREAS MEDULLATED BEFORE BIRTH.

1. Lamina perforata anterior (trigonum olfactorium).
2. Upper third of the posterior central gyrus and the posterior surface of the corresponding part of the anterior central gyrus. Lobulus paracentralis.
2^{b}. Middle third of the posterior central gyrus.
3. Septum pellucidum with the diagonal Bandelette of Broca.
   Primary cingulum of Flechsig.
   Cortico-petal fibers of the fornix inferior.
4^{a}. Uncus (gyrus hippocampi) inner center for smell.
4^{b}. Subiculum cornu Ammonis.
5. Borders of the fissura calcarina.
   Polus occipitalis.
   Gyrus descendens.
   Lower third of the posterior central gyrus (2^{c} and 5^{b}).
6. Gyrus fornicatus, posterior half of the under surface, fornix longus.
7. Oblique gyrus of the gyrus temporalis superior.
7^{b}. (?) Upper half of the posterior gyrus of the island.
8. Part of the gyrus frontalis I.
8^{b}. Adjacent part of the gyrus fornicatus.
9. Upper part of the cuneus.
10. Inner surface of the polus temporalis.
11. Oblique gyrus of the pars triangularis of the gyrus frontalis inferior, outer part of the pars orbitalis.
12. Gyrus subangularis.

AREAS MEDULLATED AFTER BIRTH.

13. Gyrus supra angularis.
14. Part of the gyrus temporalis superior.
15^{a}. Gyrus temporalis between 8^{b} and the genu corporis collosi.
15. Part of the gyrus frontalis superior adjacent to 8.
16. First parietal gyrus adjacent to 2.
17. Border of 5.
18. Foot of the gyrus frontalis medius.
18^{b}. Foot of the gyrus frontalis inferior.
19. Gyrus supra marginalis.
20^{1}. Anterior half of the third occipital gyrus.
21$_{2}$. Posterior half of the first parietal gyrus near 9.
22^{2}. Part of the island.
23$_{1}$. Gyrus occipito-temporalis.
24$_{1}$. Second occipital gyrus.
25. Gyrus fornicatus, a small portion beneath and behind.
26^{1}. Gyrus rectus adjacent to 11.
27. Middle part of the gyrus frontalis inferior.
28. Pole of the gyrus frontalis superior.
29. Rest of the gyrus supra marginalis.
30. Upper portion of the gyrus frontalis medialis.
31. Zone between the second occipital and second temporal gyri.
32. Under portion of the island.
33. Gyrus fornicatus near the præcuneus.
34. Gyrus angularis.
35. Inner surface of the gyrus frontalis superior, and the adjoining part of the gyrus fornicatus.
35^{b}. Gyrus frontalis II.
36. Temporalis II and III.

It is interesting to note that the first fibers to medullate in the brain are the primary sensory paths which extend from lower centers to the cortex. There are seven of these sensory areas on the cortex corresponding with the numbers 1, 2, 4, 5, 6, 7 and 8. No. 15 is a later extension of the primary zone 2, 2^{b}, 2^{c} and 8. Analyzing these seven zones we find that 1 and 4^{a} are primary olfactory areas connected by a band of medullated fibers with the olfactory bulb; 2, 2^{b}, 2^{c}, 8 and subsequently 15 represent the cortical zone for the sensory nerves of the skin and muscles, and have for subcenters the optic thalamus and globus pallidus; 5 is the area for sight and has its subcenter in the lateral geniculate body; 7 is for hearing and has its subcenter in the medial geniculate body, while 6 is possibly the primary sense area for taste and has its subcenter in the thalamus and globus pallidus. Thus these primary areas represent smell, touch, muscle sense, sight, taste and hearing.

The primary sensory areas have certain characteristics in common: (1) The first fibers to medullate in each one are the sensory paths from some subcenter. Later other fibers develop of the types of motor fibers, callosal fibers, arcuates and association bands, but each area has its own sequence in regard to these later systems. (2) The size of each area is proportional to the nerve or nerves supplying it, for example, the area for the skin and muscle nerves is the greatest, while the area for sight is greater than the area for hearing. (3) These primary zones can be definitely outlined in the early stages by the structure of the cortex. Moreover, the structure of the different areas is so characteristic that they can all be told apart. The structure of each area corresponds with the structure of its sense organ, for example, the many layers of the visual area correspond with the retina; the olfactory area has the fewest layers corresponding with the simple olfactory mucous membrane, while the islands of cells in the subiculum

cornu Ammonis, which are visible with the unaided eye possibly correspond with the taste buds. The area for hearing can be outlined macroscopically, for the cortex is twice as thick there as in the rest of the gyrus. The large central sensory area has a structure less characteristic corresponding with the simpler types of nerve endings. Thus each area is to be considered as a repetition in the cortex of a peripheral sense organ.

We will now take up in detail each sensory area. The first portion of the cortex to become medullated is the lamina perforata anterior (1) receiving fibers from the olfactory bulb. Later the olfactory fibers extend to the uncus (4). The cortex of these two areas is simple in structure and the medullated fibers penetrate the cortical layers. The olfactory system, which lies in the hippocampal zone, is the first to develop association bands. The first of these is numbered 3 in the list and is a band connecting the lamina perforata anterior with the globus pallidus by way of the septum pellucidum. A second band runs from the uncus through the subiculum to the cornu Ammonis. The Ammon's horn also receives an early bundle from the lamina perforata anterior by way of the inferior fornix (3). In a 9½ months' fœtus Flechsig found four bands of medullated fibers to Ammon's horn. The motor fibers of the system which begin in the large pyramidal cells of Ammon's horn and made the chief part of the fornix inferior, develop much later, 3 months after birth.

The great sensory area representing touch and muscle sense for the entire body begins to medullate next after the olfactory area. The structure of the cortex of this zone is less characteristic than the areas of special sense. But it contains in one part certain large sensory endings which Ramon y Cajal has shown are found nowhere else, while in another part it contains the characteristic giant pyramidal cells which give rise to the fibers of voluntary motion. It is the largest and most complex of the areas in regard to its primary sensory bands; that is, a number of sensory bands appear in the following order: 2, 2^b, 2^c and 5^b, then later 8, 8^b, 15 and 15^b. The sensory paths from the legs are the first to reach the cortex. They end in the paracentral lobule and in the upper third of the posterior central gyrus, extending on to the posterior surface of the corresponding anterior gyrus. The corresponding motor fibers develop from the area of the large pyramidal cells of the adjacent anterior central gyrus. Thus the sensory and motor areas are not mixed except in the sulcus. In contrast with the areas for smell, sight and hearing, the central sensory area develops motor fibers after the sensory ones. Moreover, each area develops the motor bands in the same sequence as the sensory. For example, the area 2 develops its motor fibers before 8 has medullated sensory fibers. The sequence of the types of fibers for this area is: (1) sensory, (2) motor, (3) callosal, (4) horizontal and arcuates, (5) association bands.

Flechsig has analyzed some of the sensory bands of this area, throwing much light on the relations of the basal ganglia. The following is the list of these bands: (a) Fibers from the globus pallidus to zone 2; (b) fibers from the ventro-lateral nucleus of the thalamus to zone 2; (c) a large band from the globus pallidus to zone 2; (d) fibers from the cup-shaped nucleus and center median of Luys to zone 2^b; (e) from the ventro-lateral nucleus of the thalamus to zone 2^c, and (f) from the dorso-lateral nucleus of the thalamus to zones 8 and 8^b.

The cortical area for sight (5) is around the fissura calcarina, the gyrus descendens and the occipital pole. The calcarine fissure is so deep that the area is much greater than appears. The structure of the cortex of this zone is so characteristic that the area can be sharply outlined. The association bands are late in developing, and the motor fibers run with the primary optic radiation. The primary optic radiation comes from the lateral geniculate body.

The cortical zone 6 may represent taste. It receives fibers from the thalamus in part near the pulvinar. Flechsig thinks that taste is also represented in the central sensory area. Zone 6 is connected with the subiculum cornu Ammonis and is much like it in structure.

The fibers for hearing are the first to become medullated in the temporal lobe. These fibers come from the medial geniculate body and end in a small portion of the gyrus temporalis I, not more than 1 to 2 gcm. in area. The next fibers to medullate are callosal and arcuate fibers. Possibly Türck's bundle, which develops later, is the motor path for the area analogous with the pyramidal tract.

Turning now to the second group of the primary areas, 9-13, none of these areas have projection fibers nor are they connected with the primary sense areas. Flechsig calls them automatic unknown centers. All but one, 13, develop before birth.

The group of association centers 14, 16-36 is full of interest. They all develop after birth and all begin with association bands. The division of this group into intermediate and terminal zones is both anatomical and physiological. Around each primary sensory area develops a border zone of association centers; moreover, generally speaking the earlier sensory areas receive the earlier border zones. These border zones receive their first fibers from the corresponding sensory area, and later develop other association bands. The border zone for the central sensory area is 16, 18, 18^b, 19, 22, 26, in which it will be noted that 16 corresponds with 2, 18 with 2^b, etc. The border zone for the optic area consists of 17, 20 and 24. Certain of the border zones are late in developing; for example, the one is the island of Riel, 32, and the præcunea 33, which may be the border zone for smell and taste.

The last three of the association centers 34, 35 and 36 do not develop in relation to any one primary sensory area, but rather they are in the center of a whole group of the border zones. 34 is the posterior association center, 35 the anterior or frontal area, and 36 the temporal. These centers are the last to develop and have long fibers.

Flechsig points out the enormous amount of work to be done in following the further development of the paths in the brain. The areas of the cortex do not stand out so sharply as the fiber bands become more complex, but even in

the adult it can be made out that the primary sensory areas have the most oblique and horizontal fibers, these being sensory conduction paths to other parts of the brain. The enormous numbers of fiber bundles in the adult, as well as the fact that many bundles turn abruptly in their course, makes it necessary to use pathological and special secondary degenerations as methods of research. The material is rare and the difficulties of obtaining it so great that only through coöperation between the members of the central committee and physicians and hospitals can we hope for great progress.

Flechsig takes up the results of the studies of degenerations and shows that the central sensory area as usually outlined is a mixture of true and false observations. The paths which degenerate from this central area are:

1. Cortico-spinal paths, the pyramidal tracts.
2. Cortico-bulbar paths, part in the lemniscus medialis.
3. Cortico-prontal paths, Arnold's bundle.
4. Cortico-thalamic paths (lateral nucleus).
5. Thalamo-cortical paths (ventro, lateral, central and cup-shaped nuclei).
6. Lenticular nucleus—cortico-paths.
7. Paths to the substantia nigra.
8. Cortico-quadrigeminal paths.
9. Paths of the red nucleus.
10. Paths of the nuclei of the posterior columns by way of the lemniscus medialis.

Of these 1-5 are proved for the human brain; 9 and 10 degenerate indirectly. Beside these fibers callosal and association bands degenerate. None of the pyramidal tract fibers arise in the posterior central gyrus, but rather in the lobulus paracentralis and the two upper thirds of the anterior central gyrus. The motor fibers from the lower third of the anterior central gyrus, the zone of the cranial nerves, run with the lemniscus medialis.

The fibers from the cortex to the pons and medulla (2 and 3) are not well known. They lie internal to pyramidal fibers in the pes. There are numerous bands connecting the optic thalamus and the cortex, 4 and 5. Through analyzing the degenerations, Flechsig confirms the points brought out in development, namely, that the sensory fibers end in the posterior and the motor fibers begin in the anterior central gyrus. The parietal lobe area (16) does not give degenerating projection fibers. The globus pallidus shows but few fibers which degenerate from the cortex, but the substantia nigra has many.

The study of degeneration of the optic area confirms the evidence of development. The primary optic radiation (Flechsig) which runs in the area of Vicq d'Azyrs' stripe degenerates upward from the lateral geniculate body and pulvinar to the occipital cortex. The fibers that degenerate downwards lie next the callosal fibers. In this connection Sherrington and Grünbaum's experiments on apes are most interesting, for they showed that stimulation in the region of Vicq d'Azyrs' stripe causes movement of the eye muscles; that is to say, the motor path for the eye muscles comes from the optic center of the cortex, just as the pyramidal tract starts near its corresponding sensory center. No projection fibers degenerate from 17, 17^b, 20 and 9.

The errors in regard to degeneration from the temporal lobe are due to not analyzing its different portions. Türck's bundle connects only with zone 7. It has two bundles of fibers ascending and descending and they come from different parts of the zone:

The results of degenerations in the association areas are complicated and unsatisfactory.

Flechsig now takes up the question of the relation of the motor and sensory fibers in each zone. He suggests the name of projection fields for the seven primary zones. The motor and sensory bands for each projection zone are as follows: 1. The olfactory projection zone has bands from the tractus olfactorius to the lamina perforata anterior and the uncus and descending fibers to the globus pallidus and to the ganglion habenulæ by means of the tænia thalami optici. 2. The central projection zone is the end station (indirect) of the lemniscus medialis and the superior cerebellar peduncle and the origin of the pyramidal tract for the cord and Arnold's bundle for the pons and medulla. 3. The uncus and gyrus hippocampus have several cortico-petal paths from the olfactory tracts and internal capsule and a motor path in the inferior fornix. Field 6 has an early sensory path from the internal capsule, and a later one from the thalamus. The optic area receives sensory fibers from the lateral geniculate body and thalamus and sends motor fibers to the superior quadrigeminal body. The sensory fibers of the ear path come from the medial geniculate body and the motor fibers run in Türck's bundle. The rest of the cortex is without projection fibers and if one considers the optic thalamus all parts of it have been related to the projection areas—the upper part of the thalamus to the central, the posterior to the visual, a part of the posterior and inner zone to hippocampal zone and the frontal part to the central zone and hippocampus.

The relation of the sensory and motor fibers within the projection fields is known only for the central field. The convincing experiments of Sherrington on the gorilla are confirmed in man by the myelinization. Sherrington found by careful stimulation of the cortex and subsequent extirpation of the areas that the motor fibers come from the anterior central gyrus only and not the posterior. This relation for the other zones is as yet unknown.

In connection with aphasia, Flechsig shows that Broca's field is a complex of several zones, and Wernicke's area corresponds with Flechsig's primary hearing center. The existence of complicated centers for the various phases of spoken and written language, as well as word memory, is unquestioned and there are probably multiple centers in the zones of 16-36, indeed probably a considerable part of the zones 16-36 are associated with these complicated phenomena, but to definitely locate these areas on theoretical grounds without basis of fact hinders rather than helps the development of our knowledge.

A general view of this work of Flechsig's shows that in the brain there are primarily projection centers which are the

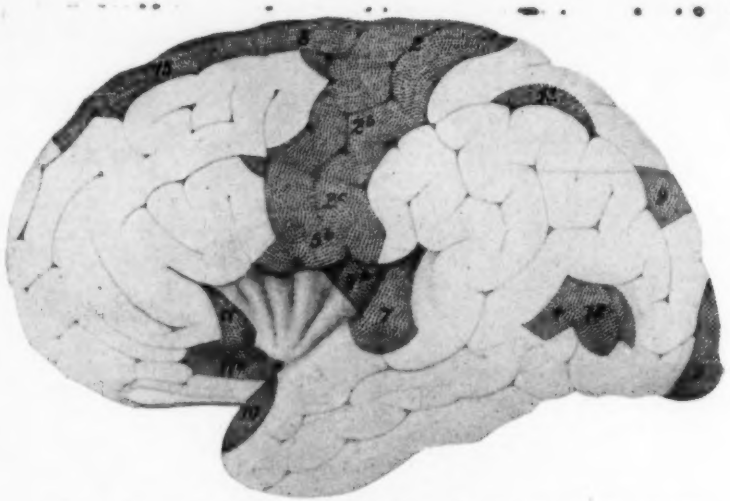

FIG. 1.—LATERAL SURFACE OF THE BRAIN SHOWING THE PRIMORDIAL AREAS, BOTH SENSORY AND AUTOMATIC, IN DOTTED ZONES.

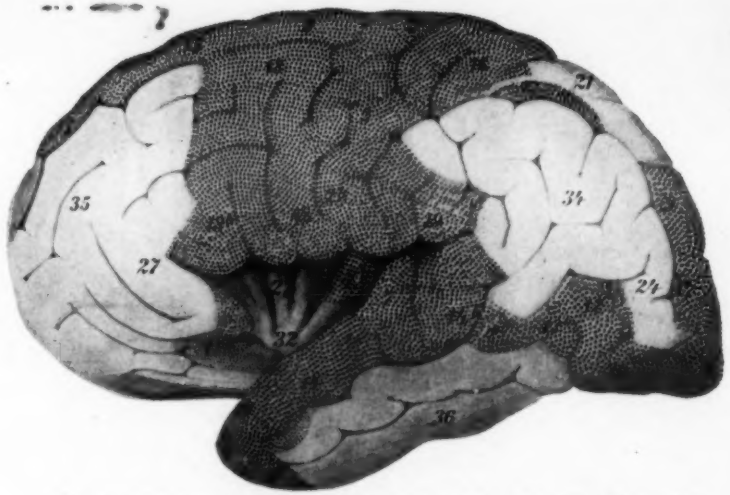

FIG. 3.—LATERAL SURFACES OF THE BRAIN SHOWING THE PRIMORDIAL AND MARGINAL ZONES.

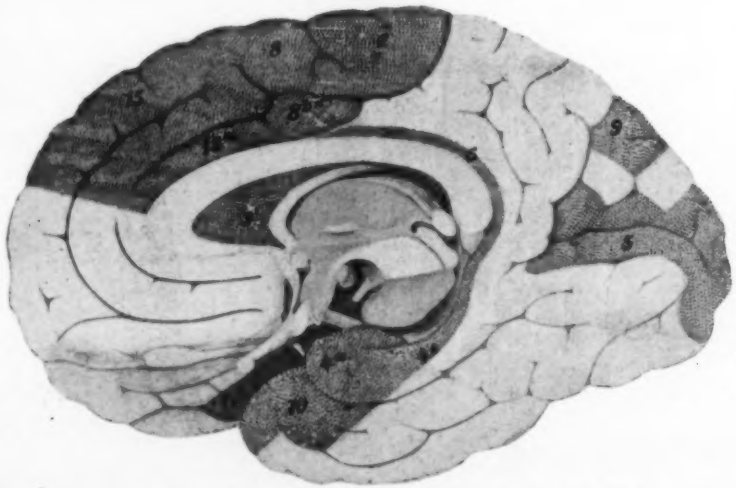

FIG. 2.—SAME ZONES ON THE MEDIAL SURFACE OF THE BRAIN.

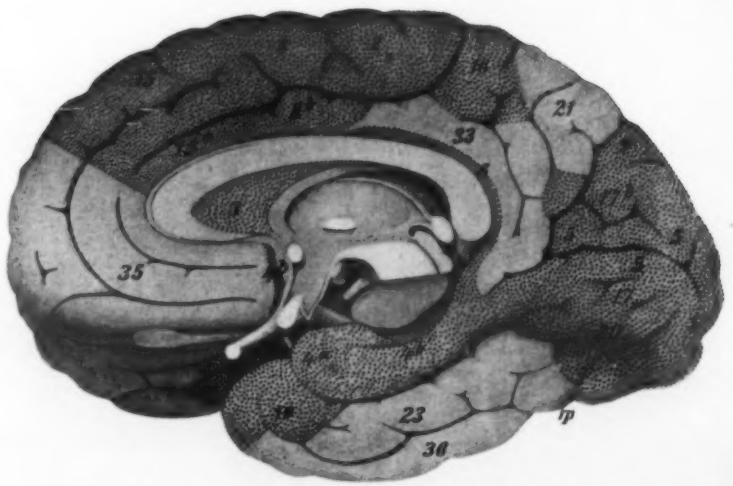

FIG. 4.—SAME AREAS ON THE MESIAL SURFACE.

areas which represent the various sensory paths and their corresponding motor tracts. They are the first to medullate, the first to develop, the first to have callosal fibers and the first to send association bands to other parts of the brain—so they are in all respects primary and fundamental. There next develop a few automatic centers of unknown meaning. The third step consists in laying down a marginal zone of association centers around each primary projection center. Each center has a group of these which develop in the same sequence as the corresponding primary center. Certain of these association areas are closely related to one projection center; for example, 16 is related to 2, but others, as for example the gyrus angularis, represent several projection centers, sight, hearing and taste, for its destruction causes a disturbance of all three of these senses. The primary projection centers are not directly connected with others; for example, no fibers run from the optic to the hearing center, etc., and the connections are made wholly through the association zones 16-36. Finally, the great association centers 34-36 are not independent isolated areas, for the great anterior association area stands in close relation to the central projection area representing the body and in slight relation to the olfactory area, while the others are more closely related to the areas of special sense.

Flechsig closes this inspiring work with some suggestions for the work of the future, the outlook for which he has made brilliant and possible. There is the field of the early development, begun by His, before medullation begins; then the whole subject of the development of the association bands. The primary relations of the fundamental association bands in their relation to the primary association centers can all be worked out on animals, perhaps especially well in the lower vertebrates. Flechsig ends with the suggestion that the whole gross anatomy of the cortex for which we have now but the outline of markings which are not fundamental, as for example the sulcus of Rolando, can now be reworked in the light of our new knowledge.

A NOTE ON THE DEVELOPMENTAL RELATIONS OF THE KIDNEY AND URETER IN HUMAN EMBRYOS.

BY AUGUSTUS G. POHLMAN, M. D.,

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The first signs of the permanent kidney (metanephros) is found in a dorsal outgrowth of the Wolffian duct close to its orifice in the cloaca. The Wolffian duct (segmental) reaches the caudal part of the enteron in embryo 76[1] (4.5 mm.). It is of even caliber throughout its course, dilating slightly as it enters the cloaca. As the duct comes into relation with the cloaca, two varieties of epithelium meet, the mesodermic epithelium of the duct and the entodermic of the gut. There must of necessity be an epithelial plate separating the duct from the cloaca, but it probably disappears with its formation.

In the slightly older embryo 80 (5.0 mm.) the duct has given off a small shoot which arises dorsally and continues the lumen of the duct into the mesodermic tissue as yet undifferentiated, in which the whole is embedded. The lumen of this bud, the renal bud, is somewhat larger than that of the duct proper and is dilated toward its blind end. The surrounding tissue has become condensed about the end of the bud and is easily recognized by its different arrangement and by its darker stain with carmine. The renal anlage is placed at the second sacral vertebra as nearly as can be estimated, in the uncertainty of the vertebræ at this stage and the difficulty in fixing the direction which might be called the right angle to the bent vertebral column. This position does not change until an older stage is reached as was verified in the models of embryo 2 (7.0 mm.) by Professor Mall and embryo 163 (9.0 mm.) by Professor Bardeen.

The renal anlage may be divided into two distinct parts in embryo 2 (7.0 mm.); a segment not surrounded by specialized mesodermic tissue, the future ureter, and a segment capped by the specialized tissue, the renal mesenchyme, the kidney and all the derivatives of the bud included within the kidney substance. The two anlages, the right and left, point dorsally from their position on the Wolffian ducts and even converge toward the middle line, and approach each other so closely that it is a matter of 50 microns separating them. The buds are at the same level and the ureter and kidney segments are of equal size.

In embryo 88 (9.0 mm.) the distal end of the bud undergoes a division into an upper and lower sprout which are enclosed in the renal mesenchyme and represent the future upper and lower pelves of the adult kidney. The renal mesenchyme in the meantime has developed in a vertical direction and is bean-shaped. Stationary up to this stage the kidney now begins a rapid wandering to its future permanent position in the body.

The sharp division into an upper and lower sprout is lost in embryo 114 (10.0 mm.). The renal mass is distinctly bean-shaped in reconstruction and rather flattened from side to side. The hilum is situated ventrally. The ureter has elongated but is still in relation with the Wolffian duct dor-

[1] This and other similar figures refer to the catalogue number in the Anatomical Collection of the Johns Hopkins Medical School.

sally. The kidneys are placed with their upper ends at the brim of the pelvis, the one a little higher than the other. The hilum of the kidney is well marked although the organ is as yet not vascularized. The two kidneys are placed with their long axes parallel and measure from tip to tip about 0.6 mm. and are about 0.2 mm. apart.

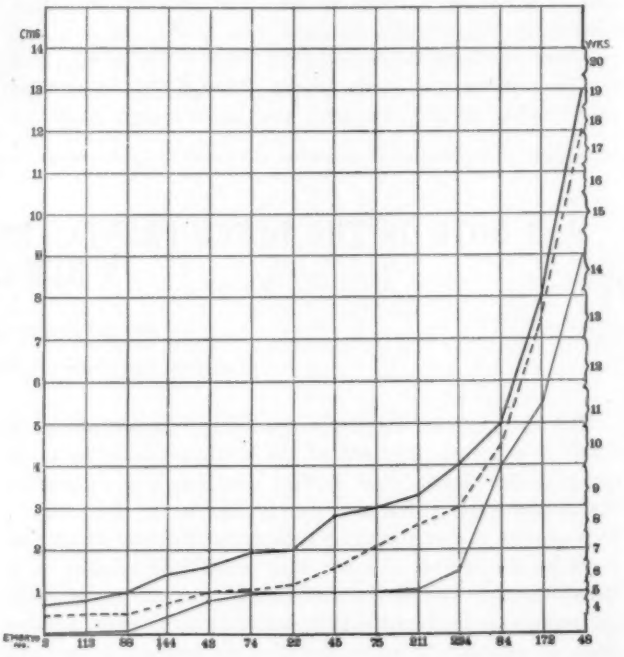
The upper border of the developing kidney reaches the third lumbar vertebra in embryo 144 (14.0 mm.). The ureter still emerges from its ventral aspect, but the relations at the lower end have changed. The ureter is rotated to a lateral position on the Wolffian duct and that portion of the duct which lay between the bud and the cloaca has disappeared (?), bringing the orifice of the ureter directly at the cloaca or into the duct at the cloaca. The kidney is without blood supply and lies behind the Wolffian body.

In embryo 43 (16.0 mm.) the kidney lies higher than in the preceding embryo. In addition it has undergone an axial rotation bringing the hilum to its mesial border, i. e., turned about 90° toward the middle line. The ureter has acquired a distinct orifice into the ventral segment of the cloaca lateral to the orifice of the Wolffian duct. The cloaca is completely divided at this stage.

The kidney arrives at its normal height in embryo 22 (20.0 mm.). The rotation is maintained and the kidneys, except that they lie closely together, are in the adult position. The vascularity is as yet problematic. In the meantime the ureter has lost all connection with the Wolffian duct and has grown into a higher and more lateral location as a fixed structure. The Müllerian ducts in this embryo are unusual in that the left duct has reached the urogenital sinus while the right lies a full slide higher up. The kidneys are about 1.0 mm. apart.

Chronologically: The Wolffian duct joins the cloaca at 4.5 mm.; the renal buds appear at 5.0 mm.; the renal buds may be differentiated into two segments, the ureter and kidney, at 7.0 mm. when they lie opposite the second sacral vertebra; at 10.0 mm. the upper border of the kidney is at the brim of the pelvis; at 14.0 mm. the ureter lies lateral to the Wolffian duct and the upper pole of the kidney is at the third lumbar vertebra; at 16.0 mm. the kidney has passed the midlumbar line and has been rotated through 90° on its long axis while the ureter has a separate orifice in the urogenital sinus; at 20.0 mm. the ureter and kidney are in the relative normal position and the Müllerian ducts have gained the sinus.

The rotation of the kidney and the displacement of the ureter at the lower end, although they occur at the same time, are distinct processes. This may be demonstrated in cases of incomplete double ureter where the ureter is divided into two segments somewhere along its course. The ventral segment proceeds from the upper pelvis of the kidney, while the dorsal branch is connected with the lower pelvis. If there were any connection between the rotation of the kidney at the midlumbar line with the lateral displacement at the lower end of the ureter, there would be evidences of such rotation along the course of the anomalous branches of the ureter, but we find the position of the two segments, the one ventral to the other maintained even in the adult with no manifestations of any rotation in an embryo with similar malformation. Comparing this variation with cases of complete reduplication of the ureter we find the relation of the two segments the same, one ventral to the other, although there is displacement of the ventral ureter in that its orifice lies between that of the dorsal ureter and the Wolffian duct. This crossing of the two ureters is only found at the lower end and does not affect the course of the ureter above. Again in all cases where there is congenital displacement of the kidney and lack of rotation or mal-rotation, the orifice of the ureter is not necessarily affected and in those cases in which the ureter is widely displaced in the female through downgrowth of the Müllerian



ducts, the kidney position and ureter course are normal otherwise.

In the accompanying chart are found curves to represent the wandering of the kidneys; the age in weeks is shown on the right, the size in centimeters on the left, and the number of the embryo plotted below. The uppermost curve is derived from the vertex-breech measurement of the embryos in question, the second and dotted curve the size of the kidney from tip to tip multiplied 10 times, the lowest curve the distance between the two kidneys also multiplied by 10. The kidney does not grow as rapidly as the body up to embryo 22 and then gains on the body size until at 130 mm., the kidney is about 1-10th the vertex-breech measurement. The distance between the kidneys remains practically the same until 88, then grows apart rapidly (the period of wandering) until 74 is gained when it remains about the same until 224 although the difference between these two embryos, 74 and 224, is 21.0 mm., or in time, about ten days. The kidneys

then grow apart even more rapidly than during the period of wandering. This quiescent time I hold to be the stage of vascularization.

It was stated in an earlier part of this article that the kidney is not vascularized until it has reached its normal height, and that it attains this position in an embryo of about 20.0 mm. This corresponds to the curve. Mr. Eben C. Hill of Johns Hopkins University has also verified this matter in the pig and the fact that the renal artery may sometimes give off the suprarenal and spermatic strengthens the point made.

The idea that the primitive upper and lower sprout of the bud correspond to the upper and lower pelves of the adult kidney is entirely compatible with the findings in the embryo and the adult. My report on the complete doubling of the ureters in embryos, Mall 172 and Keibel-Piper have confirmed the same in the most important stages in the embryology of this form of anomaly. The form of the pelvis and ureter is undoubtedly dependent on the development of the renal bud while the kidney form is controlled by the mesenchyme.

I wish in closing to express my indebtedness to Professor Mall for the use of all the numbered embryos and of his model of embryo 2, to Professor Bardeen for the loan of his models of embryos 163 and 144, to Professor Keibel for embryo Keibel-Piper and to Mr. Hill for data of his findings in the pig.

ABNORMALITIES IN THE FORM OF THE KIDNEY AND URETER DEPENDENT ON THE DEVELOPMENT OF THE RENAL BUD.

BY AUGUSTUS G. POHLMAN, M. D.,

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The vague references to the embryology made in the usual reports of renal variations are possibly a result of the anatomist not interesting himself sufficiently in what might be termed "abnormal variations." The cases are written up by the clinicians, who necessarily orient themselves as to the development of the tract from the text-books, as no scheme has as yet been worked out to which he may refer in his attempt to classify or account for the interesting and important anomalies of the kidney and ureter. Even the excellent papers of Bachhammer and of Schwarz are lamentably hidden by the obscurity of their titles.

Cases of renal malformation are comparatively rare, but they occur frequently enough to be of interest to the clinician as well as to the anatomist and pathologist. I need only mention the cases of single or misplaced kidney; to the removal of a single unilateral kidney or to the obstruction of the pelvic inlet by a misplaced organ, to illustrate the importance of a thorough knowledge of the anomalies of the urinary tract. It naturally falls upon the shoulders of the anatomist to classify variations, and as these abnormalities are usually the result of faulty development, the basis of the classification must be an embryologic one. That such a classification will include all the anomalies is quite out of the question at present. There will always be a few which cannot be explained, but the number will grow proportionately less as our knowledge of embryology advances. Before the development of the kidney and ureter had been worked out, speculations regarding the origin of abnormalities were far removed from the present accepted ideas.

The first great difficulty met with in the classification of variations from a developmental standpoint is to make the system clear and embracing, and to present the matter in such a form that it may be of use to someone beside the writer. This scheme must be based on facts in the embryology which have been verified personally, and the possible results compared with actual cases. Here again an element of error is met with in that many of the reports are crude and superficial, and too much credence must not be given to them. The exceptions are surprisingly few, and in the field covered in this paper are limited practically to one observer.

The literature referred to is necessarily small, as it was not deemed advisable to conceal any merit the classification might possess by involved references and case citings. Only those anomalies will be considered where both kidneys are present. This subject is excellently covered in the articles by Ballowitz, Moore and Morris, and the possible causes mentioned in my paper in "American Medicine."

I am obliged to set another limit to this paper in that I shall consider only those anomalies which have their origin before the third month. This excludes all congenital abnormalities which depend on the excretory function of the kidney for their manifestation—congenital cystic kidney, congenital hydronephrosis, etc., also the minor variations which are of relatively little importance, as persistent lobulation, etc. In the variations to be mentioned, the kidney is quite normal excepting in its form, and in the form of the pelvis and ureter.

The development of the renal bud has been thoroughly worked out. I will mention the article by Keibel on its earlier stages and that by Hauch on its later development. My own findings have been a confirmation of what has already been demonstrated by many investigators. I will review the embryology of the kidney and ureter by referring to the conditions present in embryos chosen from the Mall collection, from the earliest stage in the development of the tract to an age in which the kidney and ureter have assumed their relatively normal shape and position. The embryos are arranged according to their size, but the figures do not correspond exactly to those mentioned in other articles. It will be remem-

bered that all embryos of the same age are not always of the same size, and allowance must also be made for shrinkage in fixation and embedding.

The embryos are normal and in perfect series. The relations of the kidney and ureter were not only studied from the sections but modeled as well. The review presents the general development of the tract concisely and in sufficient detail for the objects of this article.

In embryo Mall 164 (3.5 mm.) the cloaca is relatively spacious. The Wolffian duct has not yet reached it and the stage is therefore too young for a study of the urinary tract.

The Wolffian ducts reach the cloaca in a trifle older stage, embryo Mall 76 (4.5 mm.), and empty well to the front in the lateral wall. There are no signs of the development of the renal buds.

The renal buds appear dorsally on the Wolffian ducts (embryo Mall 80—5.0 mm.). They arise near the cloaca and their blind ends are already capped with renal mesenchyme developed from the surrounding undifferentiated mesodermic tissue.

In embryo Mall 2 (7.0 mm.) the buds have elongated markedly and the cap of renal mesenchyme to each bud is more distinct and confined to the distal and blindly ending part. One may already separate the developing tract into two segments; the one surrounded by mesenchyme, the kidney; the other from a portion which is not, the ureter. The blind end of the bud shows no signs of dividing. The masses of mesenchyme are placed at the level of the second sacral vertebra.

The blind end of the bud shows the first signs of sprouting into an upper and lower division in embryo Mall 163 (9.0 mm.). The splitting occurs within the mesenchyme which has increased in size particularly in the vertical diameter.

The definiteness of the upper and lower division is lost in a slightly older stage, embryo Mall 114 (10.0 mm.), and the condition may more properly be spoken of as a common pelvis to the developing kidney. The two masses of mesenchyme have already assumed the typical bean shape and lie close together with their long axes parallel. The ureter emerges ventrally from each but is still dorsally placed on the Wolffian duct, although the segment of the duct between the cloaca and the ureter has shortened. The upper border of the kidney is at the brim of the pelvis.

Embryo Mall 144 (14.0 mm.). The kidney lies opposite the third lumbar vertebra and has begun an axial rotation, bringing the hilum toward the middle line. The ureter has also assumed a lateral position on the duct, and the segment of the duct between the ureter and the cloaca has practically disappeared. It may be said that the ureter has a distinct orifice into the urogenital sinus (ventral segment of the cloaca).

In embryo Mall 43 (16.0 mm.) the ureter has an orifice lateral to the Wolffian duct. The kidney is completely rotated and the hila point toward each other. The upper border of the kidney is opposite the first lumbar vertebra.

The kidney reaches its normal height about the end of the second month and then receives its blood supply, the vascularization coming directly from the aorta and occasionally from the suprarenal artery. The vessels seem to choose the nearest route and go to the hilum, the branch from the suprarenal sometimes entering the upper pole.

The ureter grows away from the Wolffian duct, embryo Mall 22 (20.0 mm.) and empties higher and more laterally. Keibel describes a trigone in his embryo Lo (24.0 mm.). The ureter assumes its relatively normal position in the same stage in which the kidney reaches its normal height or about the end of the second month. The two processes are, however, quite distinct. The change in the position of the kidney is due to the development of the distal part of the bud and its surroundings, while the change in the position of the ureter is related to the growth at the lower end of the Wolffian duct. It is interesting to note that the ureter normally loses its connection with the Wolffian duct before the Müllerian duct reaches the urogenital sinus.

The earlier development of the renal bud may be represented by three simple figures upon which the diagrams used in the later discussion of the variations will be based. Figure 1 represents the first budding from the dorsal side of the Wolffian duct at a short distance from the cloaca; Figure 2, the first subdivision of the bud within the renal mesenchyme (stage of embryo Mall 163); and Figure 3 shows Figure 1 (stage of embryo Mall 2) viewed from above. The figures are schematic, but give a fair idea of the relations found in the models of these embryos.

I take the liberty of repeating the tabulation of the steps in the development of the tract as published in "American Medicine:"

I. The renal bud arises dorsally on the Wolffian duct after the duct has reached the cloaca and at a short distance from its entrance.

II. The two buds grow dorsally, lying close together, each being capped with a mass of renal mesenchyme.

III. Each bud divides into an upper and lower sprout at some distance from the Wolffian ducts.

IV. The kidney wanders upward from a position in front of the second sacral vertebra, rotates at the midlumbar region, and finally reaches its normal height about the end of the second month.

V. It becomes vascularized after it has reached its normal height.

VI. The ureter changes its position on the Wolffian duct from dorsal to lateral and comes to empty distinct from it.

VII. The ureter loses its relation to the duct entirely and opens higher and more laterally.

It may appear that something is taken for granted when it is assumed that the upper and lower sprout of the renal bud found in an embryo of 9.0 mm. are represented in the adult by the upper and lower pelves of the kidney, especially when the division into an upper and lower sprout is replaced in an older stage by a "common pelvis." However, the assumption is a fair one: there are two sprouts, an upper and a lower, and correspondingly two pelves; in doubling of the

ureter the ventral ureter always arises from the upper pelvis as would be expected from the development; and finally, this assumption makes it easy to account for the anomalies to be considered later.

This idea that the upper and lower pelves of the kidney are determined in the earlier stages of its embryology, is contrary to the views held by some that the division of the pelvis into an upper and lower segment is due to the development of the renal parenchyma. The formation of the kidney parenchyma is secondary to the development of the ureter and its derivatives, and the idea that the growth of the kidney mechanically divides the pelvis is not substantiated in the formation of the anomalies nor does it even allow for the persistence of the lobulation normally present in the beef kidney.

It is granted in this article that the kidney is derived from a double anlage, the renal mesenchyme directly dependent on the renal bud, and that the division into an upper and lower pelvis is determined in the early embryology. It is upon these assumptions that I have based a scheme to be followed in the classification of anomalies of the tract.

No one has observed these variations at the time they were forming, and hence the scheme is merely a hypothesis. However, granting that certain changes do occur normally, is not a hypothesis that will account for the variations from this normal, and simplify the complex embryology of the developmental faults, better than no system whatever? Many renal variations are so rare that it is doubtful whether they will ever be observed in the earlier stages. Even some of the more frequent anomalies as doubling of the ureter has been reported but once in young embryos (Soulié). It was my good fortune to find two cases of complete double ureter in two embryos under the third month. One was discovered quite accidentally, and the other was found in working through the Mall collection. Two cases in over sixty embryos studied.

In all the anomalies to be mentioned none are directly pathologic because all the subjects attained an old age or died from causes quite apart from an abnormal kidney. This is no more than natural, for if the kidneys were not normal at birth, the chances for the individual reaching the age of puberty would be small. The variations are therefore only of interest from an anatomic point of view and indirectly of importance to the surgeon. The malpositions of the kidney have a greater interest to the clinician and it is my purpose to present that side of the subject at some later date. The clinical aspect is dealt with in a very thorough manner by Morris.

Anomalies of the kidney may be unilateral or bilateral, and for convenience sake the paper may be divided into three sub-headings:

A. Changes in form of the ureter.

B. Changes in form of one kidney.

C. Changes in form involving both kidneys.

Changes in form of the ureter may be present in changes in form of the kidney or they may be found in normal kidneys. The abnormalities of the ureter are dependent on the renal bud, while the anomalous kidneys result from an abnormal development of the renal mesenchyme, again influenced by the renal bud. The term abnormal refers merely to form and not to function.

A. Variations in the Form of the Ureter and Pelvis.

A 1. *Incomplete Double Ureter.*

Should the renal bud divide too early, or the division extend into the ureter segment (see Fig. A 1), that splitting found in the ureter itself would remain a permanent one and any variation might exist as a result from an exaggeration of the usual upper and lower pelves to an incomplete reduplication of the ureter. An incomplete double ureter may be defined as two ureters with a common orifice.

The more complete the division of the ureter segment, the more complete the reduplication. The pelves of the kidney would always be distinct, and it is fair to assume that each subpelvis would follow the rule for the usual normal, and divide into an upper and lower segment (to be dealt with later under A 4).

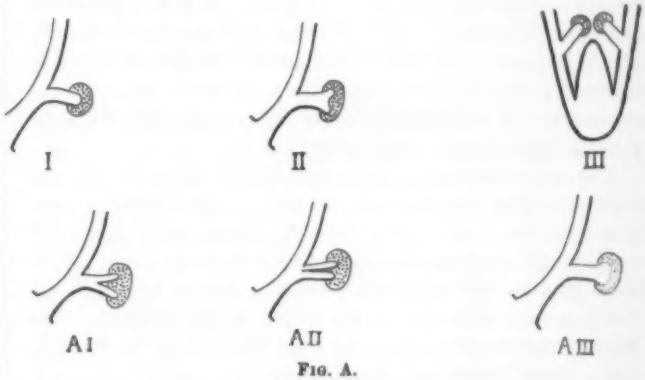


FIG. A.

The ureter from the upper pelvis will normally lie ventral to the ureter from the lower one, as will be evident from the diagram. There are exceptions to this which have a slightly different origin and these will be considered under B 2.

Cases of incomplete double ureter are the most frequent of all renal variations, and are met with yearly in almost every dissecting room. I refer the reader to the article of Schwarz, p. 172, for a review of a number of reported cases, and also to the figures in the paper of Hauch.

The rule for incomplete double ureter may be stated as follows: The pelves of the kidney are always distinct, the ventral ureter arises from the upper pelvis and there is one orifice which is usually normally placed. It is important to distinguish the incomplete double ureter from the complete variety, and in the report of cases the distinction is not often made. Fig. A 1 of the plate represents a very common type of this anomaly.

A 2. *Complete Double Ureter.*

Should the splitting of the renal bud be so complete that it is affected by the shortening of the segment of the Wolffian

duct lying between it and the cloaca, it is possible for each division to acquire a distinct orifice in the duct as is shown in Fig. A 2. This would result in complete double ureter.

The explanation seems a more likely one as the complete double ureter conforms to the rules laid down for the incomplete variety. The only differences are found at the bladder end because of the two distinct orifices.

Cases of complete double ureter are rare but the anomaly has been reported quite frequently in the adult. It was my good fortune to discover two cases in embryos under two months old; one in embryo Piper, the property of Professor Franz Keibel under whom I began to study the development of the human urogenital system, and the other, embryo 175 of Professor Mall's collection. I am indebted to both Professor Keibel and to Professor Mall for the loan of the embryos mentioned in this paper, and also to Mr. Max Broedel for extremely useful suggestions regarding the anomalies of the kidney, and the privilege of mentioning one of his own cases.

Embryo Mall 175 (13.0 mm.). This embryo is cut at twenty microns and stained in carmine. It is well preserved and entirely normal. The sex from the histology of the sex gland is male. The epithelium at the urogenital sinus is loosened a little but not sufficiently to interfere with the conformation. A model of the lower ends of the ureters and of the Wolffian duct was made X 50.

The left kidney and ureter are entirely normal. On the right side, the kidney is also normal but the ureter is completely double. The ureter from the upper pelvis is a trifle smaller and lies ventrally to the ureter from the lower pelvis. This relation is maintained until the ureters approach the Wolffian duct when the dorsal ureter swings laterally. The relation at the urogenital sinus from the midline is: Wolffian duct, ventral ureter and dorsal ureter.

As to the openings in the sinus, it is extremely difficult to say whether all three have a common orifice, or the ureters an orifice distinct from the Wolffian duct, or all three have separate openings. If the usually conceded fate of the lower part of the Wolffian duct is accepted—that it "unfolds" and enters into the formation of the bladder—any one of these possibilities may be held to be the correct one. Personally, I consider the case one of complete reduplication at a stage in which the lateral orifice is just beginning to shift to a higher and more lateral position.

Suffice it to say, that the two ureters change their relation as they approach the urogenital sinus, and that the dorsal ureter (the one from the lower part of the kidney) comes to lie lateral to the ventral ureter. This would probably be the same if the doubling were complete or nearly complete.

It will be noted that the change in position of the ureter from dorsal to lateral is at about the same time that the kidney undergoes axial rotation. Should the processes connected with the change in relation of ureter from a dorsal to a lateral position on the Wolffian duct be in any way connected with the rotation, the place of the crossing of the ureters would not be found at the lower end, and in cases where the kidney does not reach a normal height, where no rotation has taken place, the ureter would be abnormally situated—which is not the case. For these reasons, it is best to ascribe the changes in the position of the ureter to a development of the lower end of the tract and perhaps to the Wolffian duct as well.

Embryo Piper-Keibel (24.0 mm.). The same condition is found at a later stage in the development. The embryo was cut at fifteen microns and also stained in carmine. The sex is male. On the right side, there is a complete double ureter with two well defined orifices in the bladder. The ureters hold the same relation as that described in the Mall embryo and the ventral ureter swings mesial to the dorsal one as they approach the urogenital sinus. Owing to the development of the bladder, the lateral ureter opens higher and more laterally. It was found to lie in the normal position on comparison with the orifice on the other side. The ventral ureter was probably placed in a position of disadvantage for it lay in the path of the resultant of the forces—between the lateral ureter and the Wolffian duct.

I find a reference in an article by Weigert where in speaking about complete double ureter, he says: "In allen Fällen entsprach die tiefere liegende Öffnung in der Blase dem Ureter, der vom oberen Nierenbecken kam, die andere dem, der vom unteren entsprang." This agrees perfectly with my findings in the embryos and with the cases cited in the literature, with a single exception. This is a case reported by Hudson, who pictures a specimen of complete double ureter in which the ventral ureter empties higher than the one from the lower part of the kidney. The specimen was drawn after removal from the body, and it would be a most natural proceeding to uncross the ureters.

There is also an exception to the rule that the more ventral ureter comes to lie mesial to the more dorsally placed one, for according to Weigert: "In den anderen vier Fällen fand eine vollkommene Kreuzung statt, indem der vom oberen Nierenbecken kommende Ureter, der bis dahin medial vom anderen Lag, nunmehr an dessen vordere und laterale Seite zu liegen kam, und in dieser Lagerung bis an die Blase hinanging. Nach der Kreuzung und namentlich in der Nähe der Blase lagen die Ureter sehr dicht bei einander."

Exactly how this is meant is not quite clear to me. It is quite impossible to account for the condition in which the mesial ureter comes to open higher, and I am tempted to await other cases before giving up the idea that the ureter with the higher orifice must lie lateral to the more mesial opening. In a case reported by Hyrtl the orifices are described as lying side by side.

In one of Weigert's cases, he mentions the relation of the ureter from the lower pelvis as lateral to the one from the upper part of the kidney. The case is also pictured after the removal of the organs from the body and would be quite possible. The other two exceptions will be explained under B 3.

The rule for complete double ureter may be stated: that the relations of the two ureters and pelvis are the same as in incomplete reduplication, and the ureter from the upper

pelvis has the lower orifice in the bladder and lies somewhere between the higher opening of the dorsal ureter and the opening of the genital duct. The literature is reviewed by Schwarz, p. 175, and a report of twelve cases is found in the article by Weigert. The doubling according to the latter is usually on one side only.

A 3. *Common Pelvis.*

Should the division of the renal bud into an upper and lower sprout be suppressed, or should the later stage of common pelvis persist, there would be no involvement of the ureter and the form of the pelvis would not affect the shape of the kidney because that organ would have its normal origin—from one mass of renal mesenchyme. I find such cases cited by Hauch: "Man sieht die dicken plumpen Formen (casts of the pelvis), die sich garnicht in Calyces teilen, sondern einen leicht konvexen ausseren Rand haben, an welche sie die Fornices fast ohne Calyxbildung aufnehmen" Fig. 31, 32.

This must be considered a persistence of the stage of common pelvis. It is also found in pathologic conditions, and is, according to Broedel, the first sign of a beginning hydronephrosis which mechanically transforms the upper and lower pelvis into a single one. This is entirely in keeping with the view that the division is due to the development of the cortex. That the damming back of the urine may have this effect is perfectly possible, but that the condition mentioned by Hauch is a variation in the development, is also a fact.

The variation is but a slight one and has no clinical importance or particular anatomic significance.

A 4. *Multiple Pelves and Ureters.*

The sprouting of the renal bud takes place at the upper and lower poles and the question naturally arises, in case there are two pelves, the one above the other as is normal, does each pelvis divide into an upper and lower subpelvis as is the rule for the adult form? If we represent the state of affairs in a stage corresponding to an embryo 9 mm. long by a subdivision of the anlage for a doubling of the ureter, one sprout might divide and the other not as shown in Fig. A 4 a., or both might divide as in A 4 b.

In the former condition the lower pelvis would show the normal division in a kidney with complete or incomplete double ureter and two pelves, the upper simple and the lower divided. This I hold to be very uncommon, and know of no case. In the article by Hauch (Fig. 78) there is illustrated the cast of the upper part of the ureter and pelvis of a kidney in which the double subdivision is clearly shown.

The form of the kidney, if it has been developed from one mass of renal mesenchyme, is not affected by abnormalities of the pelvis, and in this I agree with Hauch: "Diese äussere Form der Niere hat keine oder nur sehr wenig Bedeutung für die Form des Nierenbeckens; ich verglich die Ausgüsse der verschiedenen, oben besprochenen Nieren mit den Abbildungen von deren Ausseren und sah, wie alle die verschiedenen Formen der Pelvis von des äusseren Form der Niere *durchaus unabhängig* sind."

The doubling of the ureter is always in one plane and the parts are arranged from above down. In case an exaggeration of the condition represented in Fig. A 4 b. be found in the adult, it would correspond to the description of that of Richmond, in which there were four divisions to the pelvis. Four distinct ducts led from either kidney, and at a point some four inches below the hilum, united into a common pelvis and afterwards were replaced by a normal ureter with normal opening in the bladder. Although the fact was not mentioned, it may be taken for granted that the pelves were distinct and that the rule for incomplete double ureter held. The division in such a marked manner is extremely rare and may be counted the least common of the variations in the form of the ureter.

The anomalies thus far discussed only affect the form of the ureter, and as has been seen, are determined in the early development of the renal bud. All these variations may be present in abnormalities in the form of the kidney with the exception of the common pelvis. In all marked congenital variations in the form of one kidney the ureter is either completely or incompletely doubled.

B. VARIATIONS IN THE FORM OF ONE KIDNEY.

It is of course understood, that the kidney form varies to some extent as it is moulded more or less to fit in its surroundings, and that these minor differences are not included in the scope of this article. Only those anomalies are to be considered which are directly dependent upon the development of the renal bud and mesenchyme. It was mentioned that as long as the kidney was developed from one secondary anlage, its form would be normal no matter what the abnormality of the ureter. It must be inferred therefore that the kidney may be derived from more than one secondary anlage if anomalies in the form are found.

Should the sprouting of the renal bud begin early, or the division be placed at different points, or the sprouts be more divergent than is usual, each division might stimulate a mass of mesenchyme, and there would be a *double* secondary anlage for the kidney. These anlages are naturally placed one above the other and might remain distinct as shown in Fig. B 1, or might fuse at an earlier or later date as represented in Fig. B 2.

Granting the condition in B 1 persistent, there would be complete doubling of the kidney, two distinct kidneys on one side with complete or incomplete double ureter, and whether the ureter be completely or incompletely double, the form of the kidney would be the same.

B 1. *Free Supernumerary Kidneys.*

A case is reported by Thielmann which gives an excellent illustration of doubling of the kidney with incomplete double ureter. The anomaly is described in great detail and I present the essentials which concern us.

The left kidney was normal but a trifle large. The right kidney was smaller but also normally formed and placed. The third kidney was situated upon the right common iliac artery, was oval in shape, and a little flattened. The ureter from the upper kidney (the right) crossed it ventrally and received the ureter from the lower kidney which ran upward to meet it at an acute angle. The openings of the right and left ureters were apparently normal.

The blood supply of the upper kidneys was usual. The lower kidney received an artery from the aorta which entered ventrally, one from the right common iliac dorsally, and one from the hypogastric at the lower pole. The anomaly was found in a sailor who had never experienced any discomfort, and whose death was in no way connected with the kidney abnormality. The renal substance was normal.

FIGS. B AND C.

A similar case is reported by Hyrtl with complete double ureter. In both cases the lower organ was misplaced and pointed hilum ventrally.

B 2. *Fused Supernumerary Kidneys.*

In case the two masses of mesenchyme fuse, three possible results are evident: (a) that the fusion of the two secondary anlages may be so complete and at such an early date that the two parts may act in the same way that one mass does (A 1 and A 2), the abnormality of the ureter being merely visible from the outside; (b) demarkation between the two may be well developed and the kidney form otherwise normal; (c) the fusion may occur at such a late date that one part was rotated before the other became fused to it and this relation would necessarily hold in the adult form.

B 2 a. *Complete Fusion.*

Barlet describes a specimen of supernumerary kidneys in a letter to the Lancet in the following manner: "On examining the kidneys it was found that the subjects possessed three, two on the left side and one on the right. The two on the left side were fused together, one being on top of the other, and externally showed two ureters springing separately along their whole length, opening into the bladder by two distinct orifices, the one being about one-fourth of an inch above the other. On section there was distinct demarkation of the two kidneys which was not visible from the exterior. All three kidneys were normal in appearance and had no connection with the cause of death."

Here is undoubtedly the same condition found in A 2, with both of the sprouts capped by a separate mass of mesenchyme which fused at an early period. It is not mentioned what the relation of the two ureters was, but it is fair to assume that they followed the rule laid down for the complete double ureter. The specimen appeals to me as a strong piece of evidence to disprove the division into an upper and lower pelvis by the growth of the parenchyma.

B 2 c. *Fused Supernumerary Kidneys with One Mass Rotated.*

In the discussion of the cases with double ureter, mention was made that two specimens had been reported by Weigert where the ureter from the upper pelvis did not occupy a ventral position. In the cases cited he found the upper part of the kidney rotated in the usual way, the hilum pointing toward the middle line, while the lower part had the hilum ventrally. He does not mention that these were supernumerary organs, and the following is therefore only inferred from like findings to be taken up later.

The two masses of renal mesenchyme, the secondary anlage for the two parts of the kidney, remained separate until one was rotated at the midlumbar region when the lower and non-rotated part was fused to upper. This would present a result which would correspond with the Weigert cases, and account for the exception to the general rule for double ureter.

Cases of supernumerary kidneys are very rare. Hepburn reports a doubling on both sides in pig, and Amick a similar finding in man. There are still other varieties which will be discussed in a later part of the paper.

C. CHANGES IN FORM INVOLVING BOTH KIDNEYS.

Thus far only the changes in the form of one kidney have been considered. There are also changes in form which affect both organs, and these are naturally due to a fusion of the two normal masses of renal mesenchyme (Fig. C). It was stated in a very superficial way in the article in "American Medicine" that it might be possible for the two renal buds to lie so closely together that they might be surrounded by one mass of mesenchyme, and that it would be difficult to distinguish this variety from cases of more or less complete fusion. This statement is withdrawn and I do not hold it possible now for two renal buds to stimulate one mass of mesenchyme; there must be two.

The fusion taking place between the masses will, of course, be a permanent one and the condition receives different names, depending on the position and the degree of fusion, but the class as a class is known as the horseshoe kidney. The varieties depend on the manner and degree of fusion.

It was mentioned that the two masses of mesenchyme lie in front of the second sacral vertebra in an embryo of 7.0 mm. (embryo Mall 2) and are at the same level. The renal buds may not lie at the same level and this is due to a slower growth and later date of appearance of one bud as was dealt with in a previous article. I find that one kidney lies a trifle higher than the other in embryo Mall 114, although both organs are still in the true pelvis. Similarly, it is quite possible to conceive that they might lie one above the other or one in front of the other.

C A. Where the masses of mesenchyme are placed at the same level, they may lie:

a. In the same relative position.

b. One ventral to the other.

C B. Where the two masses are placed one above the other:

a. One slightly in advance of the other.

b. The upper pole of one fused to the lower pole of the other.

C A a. Should the two masses of mesenchyme lie in the same relative position and at the same height, three possibilities as to the point of the fusion may be inferred:

1. Fusion at the upper poles.
2. Fusion at the lower poles.
3. Fusion centrally.

C A b. Should the two masses lie one in front of the other, the dorsally placed organ would fuse to the ventral one in such a manner that the hilum of the former would attach to the dorsum of the latter.

C B a. Should one mass of mesenchyme be placed a trifle higher than the other, the relation would be maintained in the fusion, and if one kidney were displaced, it would be the lower one, as would be dealt with more completely in a later paper.

C B b. Should the fusion occur end-to-end, the displacement, as above, will be found in the lower organ.

C A a 1. *Fusion at the Upper Poles.*

In this form of horseshoe kidney the concavity is directed downward, and according to Arneill, is the most uncommon variety. The fusion occurs probably before the organs have grown out of the true pelvis, or as soon as a distinct upper and lower pole have been formed to each mass of mesenchyme (9.0 mm.). The ureter system, being developed from the renal bud, is usually quite normal. The arrangement of the parenchyma joining the kidneys is not known, but there is undoubtedly a more or less definite line of demarkation between the two parts. The earlier the date of the fusion the more indefinite this line would be, and in cases of very late fusion, at about the time that the kidney arrived at its normal height, the growing together might be limited to the capsule. As a rule the capsule is common to both organs.

In a specimen placed at my disposal by Mr. Broedel, there is in addition to other abnormalities a horseshoe kidney fused at the upper poles. The case is unique for this variety of kidney in that the fusion is *behind* the aorta. It will be interesting to work out the arterial defect that allowed the developing masses to slip behind the aorta. The suprarenals, strange to say, were also fused. The blood supply to these organs was naturally abnormal.

Fusion at the upper and at the lower poles not infrequently reaches the normal height, and if the growing together is not too marked, the hila may be rotated to the normal position.

C A a 2. *Fusion at the Lower Poles.*

The most common variety of horseshoe kidney is found in the fusion at the lower poles. It probably has its origin at the same time as the preceding form, and why it should be more common is not known. Many cases have been reported, and as it is only necessary to establish a type in this article, I content myself with referring the reader to the work of Morris on the Surgical Diseases of the Ureter and Kidney, Vol. I, p. 56, where an excellent example of this anomaly is pictured.

The specimen mentioned shows a well-marked bridge of renal tissue connecting the two kidneys at the lower poles. Morris states that the ureters usually lie ventral to the connecting bridge but may lie behind it in case the ureters lie behind the bridge of tissue, the fusion will have been a late one—after the kidneys have been rotated.

The case of Nixon is also alluded to where a similar malposition to that described in the Broedel case was found—fusion at the lower poles and the connecting renal substance behind the aorta. The embryologic defect, probably in the arteria sacra media, which allowed this malposition, would be the same in either case, and will be considered in greater detail in a later paper on the malposition of the kidney.

C A a 3. *Fusion Centrally.*

The central fusion of the two masses of mesenchyme has received the special name of "disc-kidney." The fusion may be so complete that it is difficult to distinguish any line of demarkation between the two kidneys, and the only grosser structure by which the two organs might be identified would be the two ureters opening into the bladder at either side of the middle line.

The case of Haller, pictured in Morris's work, p. 61, is a typical disc-kidney. The organ is situated in the middle line and the two ureters emerge ventrally. A form of fusion which approaches the disc-kidney in its completeness will be mentioned later.

C A b. *Fusion of a Ventrally Placed Kidney to a More Dorsal One.*

The only possibility which remains under A is that in the dorsal growth of the two buds, one came to lie farther back than the other and that fusion took place in this position.

In a case mentioned by Morris, there is a variety of fusion which does not resemble any form of horseshoe kidney thus far described. "The two kidneys formed an irregularly shaped mass which weighed thirteen ounces, and was lying on the front of the promontory of the sacrum. It was not horseshoe-shaped and the vessels and ureters were arranged most unusually. The central part of the mass was fissured by a sulcus, in which the ureter for the left kidney coursed downwards and the vein for the same upwards, passing into the vena cava just above the junction of the two iliacs. In the right half of the mass the ureter and vessels, instead of being situated centrally, were on its outer side; the ureter being in front of the vessels as on the left and as is usual in fused kidneys." "The renal substance, to the naked eye, was healthy."

I think this explanation of the anomaly could be made: That the two masses of mesenchyme were normally placed

excepting that one was in front of the other, and that a fusion occurred between the front edge of the dorsal mass (about the hilum) and the touching edge of the ventrally situated mesenchyme. Both organs were in the pelvic inlet and a later rotation, probably a purely mechanical one to gain room, turned both ureters toward the same side. The one would in this case undergo a normal rotation and the other, one in the opposite direction. In the specimen of two kidneys pictured by Morris, one must have been placed a little in front of the other.

C B a. *Fusion of a Lower Kidney to a Higher One.*

In all the variations in the form of the two kidneys thus far considered the two organs were placed at the same level. In embryo Mall 114 (10.0 mm.) one kidney was found lying a trifle higher than the other, although both organs were still in the true pelvis. Should a fusion occur the lower kidney would remain in the lower position.

This type of fusion is found in a case of horseshoe kidney placed at my disposal by Dr. W. H. Lewis. The two kidneys lie on the midline and the right organ is a trifle higher than the left. The mass is somewhat irregular, but the two kidneys are well divided by a longitudinal fissure. The ureters emerge ventrally and empty normally in the bladder. The mass was in a low position and lay upon the bifurcation of the aorta.

These minor differences in height are difficult to tell from disc-kidney, but as a rule the two parts are more distinct. When the difference in the height is more marked, and the organs lie above the point of rotation, the lower kidney is usually displaced and crosses to the opposite side—crossed dystopia (see McMurrich's article).

The fusion of a higher kidney to a lower kidney may be any variety from a disc-kidney to an end-to-end fusion which is discussed in the next sub-heading. The blood supply to these organs is more or less abnormal, depending on the degree of the malposition. Normally placed horseshoe kidneys may have a normal blood supply.

C B b. *End-to-end Fusion.*

In a case reported by Broesicke, two kidneys were fused end-to-end and both organs were placed to the left of the middle line. The arrangement of the ureters was strikingly abnormal. The upper ureter arose from the mesial surface of the mass and the lower one from the lateral side. The openings of the ureters in the bladder were normal. The specimen is one of "sigmoid kidney." Broesicke agrees with Schultze that the anomaly is explained on the basis of the embryology.

Here the two masses of mesenchyme were placed one above the other and fused after the rotation of the upper kidney took place. The case is similar to the variety discussed under B where the upper half of the kidney rotated and then became fused to the lower part.

These end-to-end fusions are all of relatively late stages. Should the two masses fuse at a very early date, there would be difficulty in distinguishing the two kidneys. The mass would be different from the centrally fused horseshoe kidney in that the ureters would be placed one above the other. This form of kidney is reported by Morris and pictured on page 49. The variety is interesting in the discussion of the causes of the rotation.

C C. *Fusion of Supernumerary Kidneys of Opposite Sides.*

Granting that the doubling of the kidney may be found on one or both sides and that fusion between the masses of mesenchyme on the same and opposite sides may take place, a number of combinations may occur which are represented in the scheme below. Naturally all these cases have not been reported, but this does not preclude the possibility of their being found. It must be remembered that fusion between a normal mass of mesenchyme on one side and two masses on the other may also occur, and the resulting form is easily deduced from the scheme.

In the first series, the upper and lower masses are presented as remaining free:

a. Horseshoe kidney with free supernumerary kidneys below.
b. Horseshoe kidney with free supernumerary kidneys above.
c. Double horseshoe kidney (no cases reported).

In the second series, the upper masses are fused to the lower:

d. Horseshoe kidney with fused supernumerary kidneys below.
e. Horseshoe kidney with fused supernumerary kidneys above.
f. Fusion of all four parts (e and f reported).

In the third series, the organs are placed at different levels:

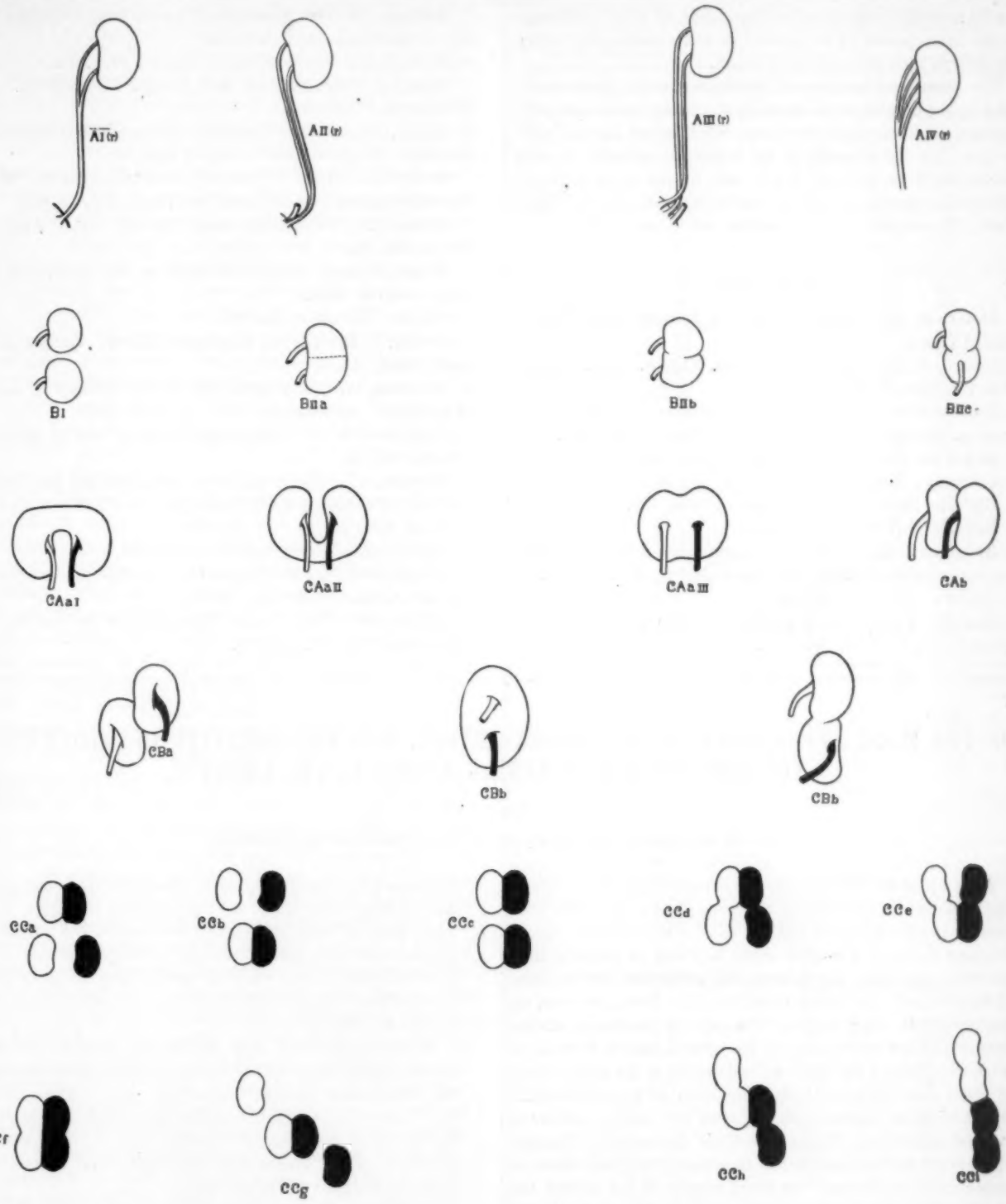
g. Horseshoe kidney with free supernumerary above and below.
h. Horseshoe kidney with fused supernumerary above and below.
i. End-to-end fusion of all four parts (none reported).

C C e. *Horseshoe Kidney with Fused Supernumerary Kidneys Above.*

A specimen is described by Oleson of four kidneys in a human being. The mass was fused at the lower poles, and on each side there appeared to be a division into two. From the report it is gathered that the ureters were incompletely doubled, and that the author identified the two supernumerary organs above.

C C f. *Fusion of All Four Parts.*

Morris pictures an anomalous kidney mass, p. 54, the case of Batallus, which I take to be the fusion of four kidneys. The mass presents "a quadrilateral appearance" and each ureter divides into two. There is, of course, a question as to the definiteness of this statement, but the case seems to conform, and there is no reason why double kidneys on either side should not behave like a central fusion of the disc-kidney variety.



There are some abnormalities which are not included in this paper, and only those have been mentioned which seem to find an explanation in the development of the tract. The embryology of these anomalies is not very complicated when one follows the development closely. The supernumerary kidney, like the double ureter, has a distinct importance in the study of normal embryology, and serves to substantiate the rule which was assumed in the first part of this article,

that abnormalities in form are dependent on small variations in the development of the renal bud and mesenchyme before the embryo reaches a size of 10.0 mm.

The letters and numbers of the figures in the plate correspond to the numbers and letters in the paper, and to simplify matters, all those which have been reported are marked with an (r). In the schemas of the horseshoe kidneys, the one ureter has been pictured black, and in the supernumerary kidneys the ureters have been omitted and the one side made black; the concave side representing the hilum in each.

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ON THE FIRST APPEARANCE OF THE RENAL ARTERY, AND THE RELATIVE DEVELOPMENT OF THE KIDNEYS AND WOLFFIAN BODIES IN PIG EMBRYOS.

By Eben C. Hill.

From the Anatomical Laboratory of the Johns Hopkins University.

A review of the literature on the development of the kidneys and Wolffian bodies in pig embryos, shows but little concerning the blood supply and the relative size of these organs. Perhaps the most extensive study is found in Keibel's Normentafel, in which the anlages and subsequent development of these glands are traced histologically. Here, however, no measurements except those of the embryos are given. In the accounts of the embryology of the arterial system there is no work which shows the relative development of the blood supply to these two glands. At the suggestion of Dr. Pohlman, I measured these organs in pig embryos, and made a number of arterial injections. These injections demonstrate the first appearance and development of the renal artery and afford an opportunity to compare the blood supply of the kidney and Wolffian body in pig embryos ranging from 20 mm. to 75 mm. in length. The measurements show the relative size of these glands at various stages from 20 mm. to 132 mm.

Material and Methods.—The abundance of material from the slaughter houses offered every facility for numerous measurements and repeated injections upon live pig embryos, while the valuable collection of human embryos belonging to Professor Mall afforded opportunity to compare the human fetal development with that of the pig. The pig embryo is especially adapted for the study of the Wolffian bodies because of the relatively larger development of this organ in the pig than in man or rabbit.

Measurements.—As each uterus was opened the vertex-breech lengths of the embryos were made and measurements of the kidneys and Wolffian bodies were taken. These measurements were then averaged and the results were used in plotting the curves of their relative development. In cases where the growth of these organs was abnormal, their measurements were not included in the averages.

Injections.—In making injections, India ink, diluted to one-third of its commercial strength, was used.[1] In certain instances, pure water formed a precipitate, when added to the

[1] Taguchi's method modified. Arch. f. Mikr. Anat., 1888.

commercial ink, but this could be easily remedied by the addition of a small amount of weak ammonia. Lamp-black solutions proved to be most unsatisfactory, because of the difficulty in obtaining solutions of similar consistency. Frequently, also, this injection mass would clog the needle of the syringe. All injections were made through the hypogastric artery before the embryo was removed from its surrounding membranes. In this way the organism was protected from undue pressure and from injury in handling. During the operation, the embryo still attached to a portion of the uterine wall was immersed in warm water. A ligature was passed around the umbilical cord close to the wall of the uterus, thereby preventing infusion of the injection mass through the uterine tissues. The hypogastric vein was then pricked with a needle, thus reducing the pressure in the circulatory system consequent upon the entrance of the injection fluid. All injections were made with a fine hypodermic syringe by piercing the hypogastric artery close to the abdominal wall. To obtain an even flow it was necessary to have a perfectly adjusted syringe devoid of all capacity markings. With such a syringe an even pressure of about one drop in three seconds was maintained with little difficulty. By watching the femoral arteries the progress of the fluid was followed and an injection without extravasation was obtained. After the injection, the membranes were removed and a measurement of the body length was taken. Then an abdominal incision was made and the liver and portions of the intestines were dissected away, exposing the kidneys and Wolffian bodies. In the smaller stages it was necessary to displace the Wolffian body in order to obtain a measurement of the kidney, as at this time it is completely hidden by the larger gland. The positions of these organs relative to the vertebral column were also noted, though this was more easily discerned after clearing.

Clearing.—To clear the specimens, the Schultz method, modified by Dr. Mall, was used. The specimen was first thrown into 95 per cent alcohol until completely shriveled. As a rule forty-eight hours were sufficient to accomplish this result. Then the upper portion of the embryo, just above the twelfth thoracic vertebra, was dissected off, leaving the Wolffian bodies and the kidneys attached to the body wall. Thus during the clearing in a 2 per cent solution of sodium hydroxide, which followed, the action of the reagent could be watched and controlled. This usually took from four to eight hours. When the tissues had become translucent in this medium the specimen was transferred to 20 per cent glycerine for a week or more, and was then placed in absolute glycerine where it became transparent. Upon complete clearing the vertebral column was shown quite prominently and its position relative to the kidneys and Wolffian bodies was noted. In this absolute glycerine the organs became so firm that the remaining portions of the body wall were removed and the specimen was then placed between watch crystals for microscopic study.

Injections were also attempted through the liver while the embryo was alive, but the vascularization of the Wolffian bodies is such that venous injections were most unsatisfactory. The causes of this will be taken up later.

TABLE SHOWING THE LENGTH IN MILLIMETERS OF THE KIDNEYS AND WOLFFIAN BODIES OF PIG EMBRYOS.

The measurements were made from vertex to breech, and include all of the embryos in each uterus. In case of asymmetric development of these glands in any embryo averages were made of the lengths of both organs.

RELATIVE SIZE OF THE KIDNEY AND WOLFFIAN BODY AT DIFFERENT STAGES.

	Vertex-Breech.	Kidney.	Wolffian Body.
Uterus 1	20	1.2	7.3
	21	1.2	7.3
	20	1.1	7.4
	23	1.2	7.2
	22	1.3	7.1
	21	1.0	7.3
	20	1.2	7.2
Uterus 2	28	2.5	9.0
	28	2.6	8.0
	20	2.5	8.5
	27	2.4	9.2
	28	3.0	7.0
	29	2.7	8.7
Uterus 3	30	2.8	8.6
	32	3.2	8.8
	30	3.5	8.7
	33	3.4	8.8
	29	2.9	8.9
	34	3.5	8.7
Uterus 4	31	3.9	9.2
	33	4.0	9.1
	33	3.8	9.0
	35	3.7	9.1
	33	4.1	8.9
Uterus 5	38	5.0	10.0
	39	5.5	9.5
	38	5.5	10.0
	38	5.0	10.0
	39	5.0	10.0
	39	6.5 abnormally large.	8.5 abnormally small.
Uterus 6	39	5.5	10.0
	39	5.5	9.5
	38	5.7	9.5
	39	5.5	10.0
	40	5.6	10.2
Uterus 7	40	5.8	10.0
	41	5.9	10.0
	40	5.9	11.0
	42	5.9	11.0
	41	5.8	10.0
	43	6.0	11.2
	41	5.8	10.5
	42	5.9	11.3
	39	5.6	11.5
	41	5.9	10.0
Uterus 8	49	8.0	11.5
	48	7.0	12.0
	48	6.5	11.1
	49	6.0	12.0
	48	7.0	10.0
	49	7.3	11.0
	48	7.5	11.5
	49	8.0	10.5
Uterus 9	49	7.3	11.0
	49	7.8	10.5
	49	6.8	12.0
	48	8.0	10.0
	50	7.8	10.5
Uterus 10	57	9.2	11.5
	57	9.0	11.4
	56	9.2	11.2
	58	9.0	11.5
	57	9.3	11.0
	59	9.5	11.5
	58	9.0	11.4

	Vertex-Breech.	Kidney.	Wolffian Body.
Uterus 11	60	9.2	11.5
	59	10.6 abnormally large.	9.8 abnormally small.
	57	9.5	11.4
	61	9.4	11.5
Uterus 12	62	9.4	11.5
	60	9.3	11.0
	64	9.5	11.7
	60	9.0	11.3
	64	9.5	11.0
	63	9.7	10.5
Uterus 13	67	11.5	11.5
	67	11.5	11.0
	69	11.0	12.0
	70	11.5	11.0
	67	11.4	11.3
	67	11.5	11.0
Uterus 14	68	11.7	11.8
	67	11.5	12.0
	68	11.5	11.4
	69	11.4	11.5
	67	11.2	11.2
	68	11.5	11.7
	67	11.6	11.4
Uterus 15	84.5	14.4	10.0
	84.5	14.5	10.0
	84.0	15.0	10.0
	85.0	14.6	9.5
	84.5	14.2	11.0
	84.0	14.0	11.0
	85.0	17.2 abnormally large.	8.0 abnormally small.
Uterus 16	85.0	14.5	10.2
	84.6	14.7	10.0
	84.4	14.3	10.5
Uterus 17	90.0	13.0	9.7
	91.0	15.3	9.5
	90.0	15.0	9.7
	89.5	14.6	10.0
	90.1	15.0	9.6
Uterus 18	94.3	15.7	9.2
	94.5	15.9	9.0
	94.3	15.6	9.0
	94.0	15.5	9.8
	94.4	15.7	8.7
	94.3	15.6	8.9
Uterus 19	112.2	18.3	7.1
	112.5	18.4	7.0
	111.9	18.0	7.1
	112.0	18.0	6.7
Uterus 20	120.6	19.4	5.6
	121.0	19.6	5.4
	120.8	19.5	5.5
	120.7	19.5	5.5
Uterus 21	132.4	20.0	At this stage the Wolffian bodies have become so atrophied at the anterior end that accurate measurements are impossible.
	132.6	20.3	
	131.9	21.0	
	133.0	20.5	
	132.5	21.0	
Uterus 22	155.1	23.6	
	156.9	23.8	
	157.2	24.0	
	155.5	23.8	

A study of the foregoing tables shows comparatively little variation in the body lengths of the embryos in each uterus. In the cases of abnormal development of the kidney, it is interesting to note the corresponding size of the Wolffian body. That a balancing of function exists between these two glands is suggested by the fact that an embryo having an unusually large kidney development has correspondingly small Wolffian bodies.

In the accompanying diagram, the curves are constructed from the foregoing measurements and represent the growth of the kidney and Wolffian body as compared with the general development of the embryos. In the case of the Wolffian body it is impossible to properly depict the atrophy of this gland by a curve, because the degeneration which occurs mainly in the cephalic end is marked rather by a decrease in width than in length.

Embryological Development of the Wolffian Body and Kidney.—As is well known, the Wolffian body finds its anlage in the Wolffian duct which is developed as a solid mesoblastic cord of cells, lying close to the vertebral column in the abdominal cavity. This cord of cells acquires a lumen and penetrates the urogenital portion of the cloaca. Adjacent to the anterior end of this duct on the outer side lie the mesoblastic cells which later become the Wolffian body. The rapid growth of this gland from the 7 mm. stage to that of 10 mm. has been described by Allen.[2] He states that between 7 mm. and 8 mm. the Wolffian body is almost doubled in size, while at 10 mm. it is half as broad again, and has also increased dorso-ventrally. MacCallum has found at this same stage of 8 mm. well-formed glomeruli and tubules throughout the whole length of the organ.[3] The Wolffian duct is also fully developed and according to Minot is larger proportionately at this stage than at any time later.

The Wolffian bodies are elongated structures attached to the mesentery close to the dorsal wall. The anterior and posterior ends curve toward the median line, though the curve is more exaggerated in the case of the former. The anterior end tapers slightly when the gland is at its fullest development, and it is in this portion that atrophy begins. The Wolffian duct lies as a ridge on the flat dorso-lateral surface of the gland and extending from the anterior end empties into the urogenital part of the cloaca. During its course across the organ it sends out at regular intervals tubules which are very much contorted and almost encircle the periphery of the organ. The arteries supplying the gland penetrate the dorso-medial portion and form with the distal end of these tubules glomeruli similar in structure to those of the true kidney, though slightly larger.[4]

The venous system in this gland consists of branching capillaries which follow the periphery and anastomose profusely in the midst of the organ. Injections consequently resulted in almost solid masses of black with no definite structure. The relation of the arteries and veins is easily discerned by sections and shows a vascular arrangement similar to that of the kidney. The arteries and veins in the glomeruli are sur-

[2] Allen, B. M., Embryonic Development of Ovary and Testis of Mammals, American Journal of Anatomy, Vol. III, No. 2.

[3] MacCallum, J. B., Notes on the Wolffian bodies of Higher Mammals, American Journal of Anatomy, Vol. I, No. 3.

[4] MacCallum, op. cit.

rounded by an epithelial membrane similar in structure to Bowman's capsule of the kidney, and the histological structure of the tubules is also quite similar. Each tubule begins at the glomerulus as a somewhat constricted tube and widens in the middle, narrowing again before reaching the duct. The space between the tubules, according to Minot, is lined with epithelium and gives evidence of a sinusoidal circulation.

Kidney.—The kidney, as has been long known, arises as a tubular diverticulum from the Wolffian duct near its entrance into the cloaca. This broadens at its distal end, forming the renal pelvis, while the tubular portion becomes the ureter. When the embryo is 12 mm. in length the pelvis of the renal anlage is between the fifth lumbar and second sacral vertebrae, just below the division of the dorsal aorta into the right and left hypogastric arteries.[1]

From this stage in the development of the kidney and Wolffian body, which has already been so thoroughly worked out, the following figures trace the relative development of these glands and their blood supply.

It was found best in order to avoid confusion to omit from the drawing the adrenal glands, ureters and Wolffian ducts as well as the ovary or testis. In this way the comparison between the Wolffian body and kidneys is more easily illustrated.

In Figure 1 the kidney is moving in a cephalic direction toward its permanent position and has at this stage received no apparent blood supply. To ascertain that no injection had reached the organ it was completely mascerated and studied under high power. No suggestion of arterial supply was discovered and it is probable that the renal arteries in the pig embryo as in the human fetus do not penetrate the kidneys until they have reached their permanent position. It was supposed that these arteries might enter the kidneys earlier and grow up the aorta as the organ ascended, but injections and examinations of sections show no vascularization until the kidney has reached its permanent position. That the absence of injection fluid in the kidney at this stage was not due to imperfect injection is evinced by the fact that the finest capillaries of the lower extremities and viscera are completely filled.

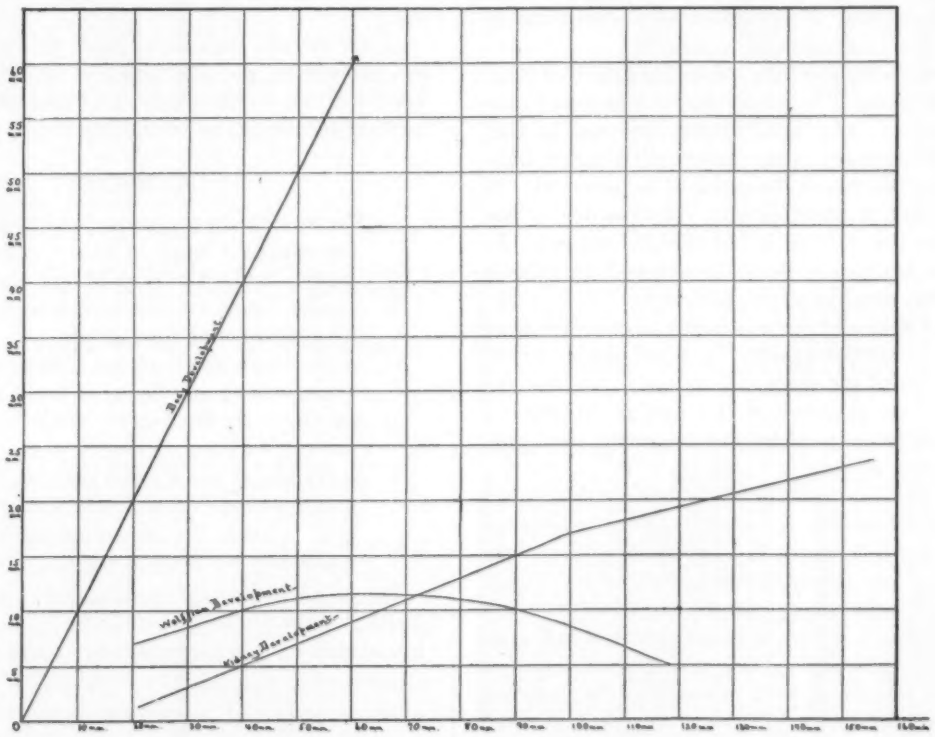

Diagram showing the relative size of the kidney and Wolffian body as compared with the length of the embryo. Averages were made of the measurements of the embryos in each ulterus except in certain cases of abnormal development, when only the average of those normally developed was taken.

As in the human embryo, rotation of the kidney occurs before the entrance of the blood supply. According to Pohlman, this rotation takes place in the human embryo at 14 mm.[2] My study of sections of pig embryos places the rotation of the

[1] Lewis, F. T., The Gross Anatomy of a 12 mm. pig, Vol. VII, Americal Journal of Anatomy.

[2] Pohlman, A. G., Concerning the embryology of Kidney Anomalies, American Medicine, Vol. VII, No. 25, pages 987-990.

kidneys in this genus between 12 and 15 mm. The vascularization of these glands in the human fetus, as has also been proved by Pohlman, takes place during the time the embryo is increasing in length from 25 mm. to 30 mm. In the pig embryo, the first appearance of the renal artery which I have been able to demonstrate, occurs at 28 mm.

The Wolffian bodies at this stage are highly vascularized and the glomeruli are fully developed.

The number of arteries leading from the aorta to these glands during the early stages is approximately the same, while the increase in size is proportional to the body growth.

Figure 2 shows the entrance of the renal artery at the earliest stage, though only a very slight arterial supply to the glomeruli was discernible. The Wolffian body is more highly vascularized and has broadened and lengthened.

In Figure 3 the glomeruli of the kidney have received their arterial supply while the Wolffian arteries have increased considerably in diameter. The organ has also increased in size. The heavy injection shown in the dorso-medial region indicates as in the first two figures the region of the glomeruli. It is around these that the tubules end. The position of the organs relative to the vertebræ is but slightly changed. At this stage the development of these vertebræ and the kidneys and Wolffian bodies seems quite proportional.

Figure 4 shows the rapid increase in the vascularization of the kidney and its relative growth. A slight atrophying of the anterior portion of the Wolffian body has begun, and the arterial supply of the glomeruli of this part of the gland is less extensive than in the posterior end, where the blood supply still continues to increase.

In Figure 5 the four anteriorly situated arteries to the Wolffian body have decreased in diameter and the accompanying glomeruli show consequent lack of blood supply. The posterior glomeruli on the other hand are still well vascularized, and there is no atrophy of the gland itself in this portion. The kidney manifests a further development, both in the number of its glomeruli and in its uniform growth.

In Figure 6 it was found to be impossible to separate the two glands so that we find the Wolffian body closely attached to the lower ventral border of the kidney. The atrophy of the anterior portion of the Wolffian body has become most evident, though this degeneration is more manifest in width than in length. The glomeruli in this part of the gland have practically no blood supply and several of the arteries have entirely disappeared. By this time the cortex of the kidney has become so thickened that only the blurred outlines of the arteries are discernible.[1]

Figure 7 shows the complete disappearance of the anterior Wolffian arteries and the absence of glomeruli in this portion of the gland. Three of the posterior arteries still persist and supply the glomeruli of this part of the organ, though one of these seems ready to atrophy. In the kidney development there is little more to be noticed except a general increase in size and blood supply.

Injection methods give no further information concerning the Wolffian body after this stage. It is well known, however, that the anterior portion continues to rapidly diminish in width and later in length, and that the remaining tubules are finally claimed by the testis or ovary.

In the male the Wolffian duct becomes the canal of the epididymis, the vas deferens and the common ejaculatory duct, and the remains of the gland itself become the vasa afferentia, ductuli aberrantes and the rudimentary paradidymis.

In the female, the duct becomes the longitudinal duct of the parovarium and the hydatids of Morgagni, while the tubules of the Wolffian body are transformed into the rudimentary tubules of the parovarium and of the paroophoron.

SUMMARY.

A. The renal artery penetrates the kidney when the embryo has attained a length of 28 mm.; rotation of this gland having occurred between 12 mm. and 15 mm.

B. A balancing of function is suggested by a study of the measurements of these glands.

C. As the blood supply to the kidney increases there is a corresponding atrophying of the Wolffian arteries.

D. Atrophy of the Wolffian arteries is first evident when the embryo is 45 mm. in length.

E. As atrophy of the Wolffian body itself continues, the sex gland becomes more firmly attached to the posterior portion, and the remaining tubules and duct are claimed by the ovary or testis.

Before completing this article, I wish to thank Professor Keibel, of the University of Freiburg, for the privileges of his laboratory, in which a portion of this work was done.

[1] Recent injections which were cleared in a saturated solution of sodium hydroxide instead of a 2% solution bring out quite distinctly the course and distribution of the renal arteries and the location of the glomeruli in the kidneys of pig embryos 68 mm. and 75 mm. in length. The general arrangement of these arteries and glomeruli is similar to that found in figure five.

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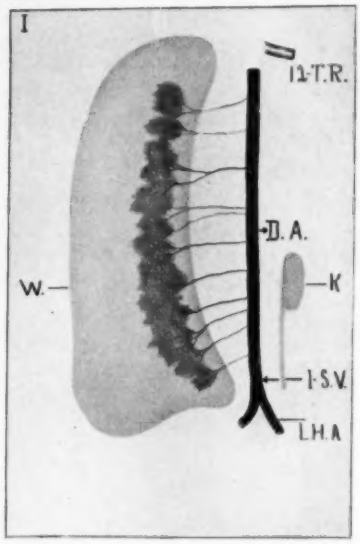

FIG. 1.—The right Wolffian body and the left kidney of a pig embryo 20 millimeters long; injected through the hypogastric artery with India ink. The length of the Wolffian body is 7.3 mm., and the kidney is 1.2 mm. long. D. A., dorsal aorta. K., kidney. L. H. A., left hypogastric artery. W., Wolffian body. 12 T. R., twelfth thoracic rib. 1 S. V., first sacral vertebra.

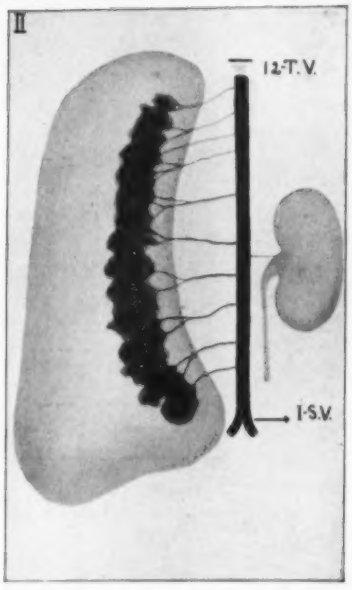

FIG. 2.—The right Wolffian body and the left kidney of a pig embryo 28 mm. long; injected through the hypogastric artery with India ink. The entrance of the renal artery is first demonstrated at this stage. The length of the Wolffian body is 8.5 mm., and the length of the kidney is 2.6 mm. 12 T. V., twelfth thoracic vertebra. 1 S. V., first sacral vertebra.

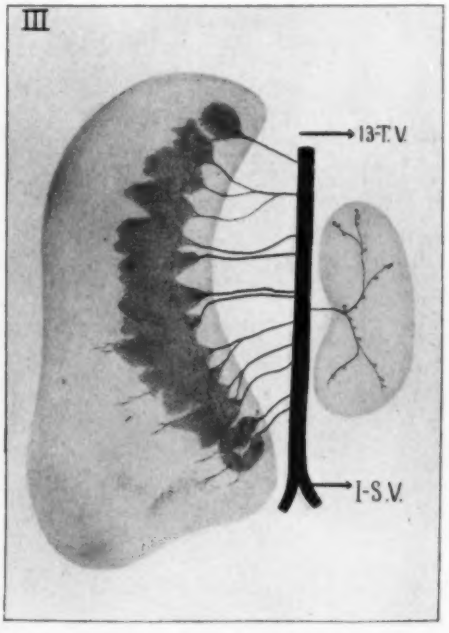

FIG. 3.—The right Wolffian body and the left kidney of a pig embryo 33 mm. long; injected through the hypogastric artery with India ink. The length of the Wolffian body is 9.1 mm., and the kidney is 3.9 mm. long. 13 T. V., thirteenth thoracic vertebra. 1 S. V., first sacral vertebra.

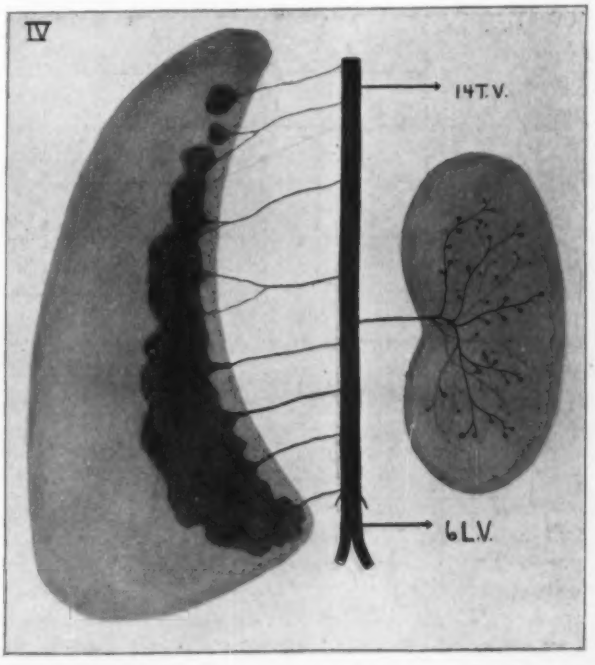

FIG. 4.—The right Wolffian body and the left kidney of a pig embryo 45 mm. long; injected through the hypogastric artery. The length of the Wolffian body is 10.6, and the length of the kidney is 6.3 mm. 14 T. V., fourteenth thoracic vertebra. 6 L. V., sixth lumbar vertebra.

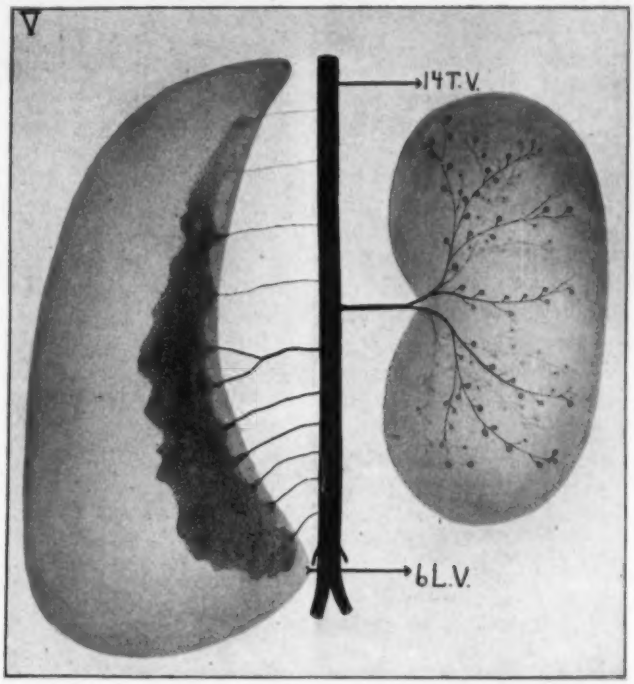

FIG. 5.—The right Wolffian body and the left kidney of a pig embryo 54 mm. in length; injected through the hypogastric artery. The length of the Wolffian body is 11.2 mm., and the length of the kidney is 8 mm. 14 T. V., fourteenth thoracic vertebra. 6 L. V., sixth lumbar vertebra.

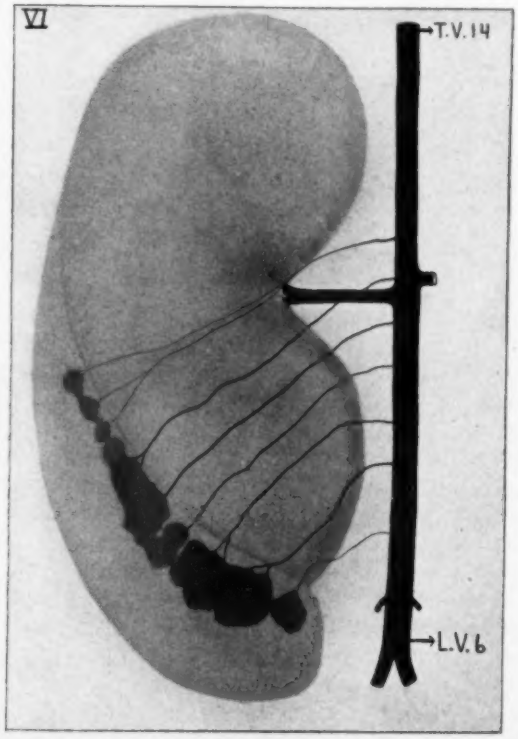

FIG. 6.—The right Wolffian body and right kidney of a pig embryo 68 mm. long; injected through the hypogastric artery with India ink. The length of the Wolffian body is 11.3 mm., and the length of the kidney is 11.5 mm. 14 T. V., fourteenth thoracic vertebra. 6 L. V., sixth lumbar vertebra.

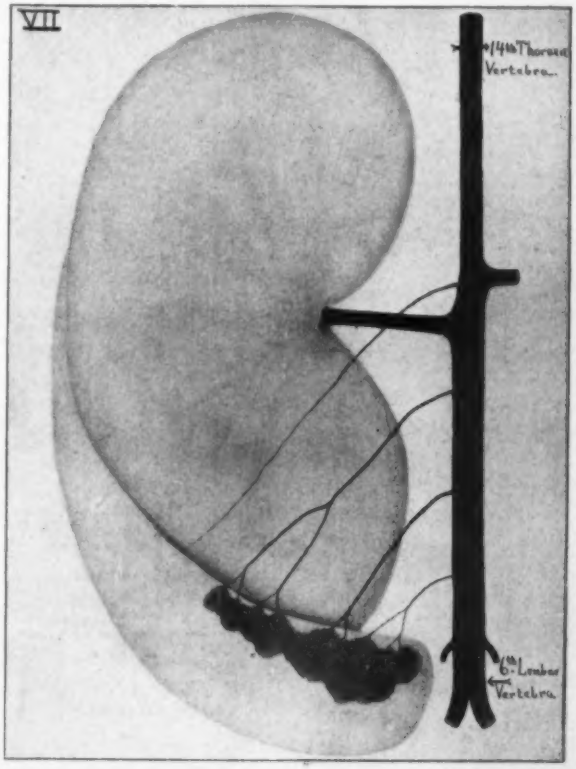

FIG. 7.—The right Wolffian body and right kidney of a pig embryo 75 mm. long; injected through the hypogastric artery with India ink. The length of the Wolffian body is 10.9 mm., and the length of the kidney is 12.2 mm.

HIGH BIFURCATION OF THE BRACHIAL ARTERY WITH REUNION AT THE ELBOW.

BY MINERVA HERRINTON.

The abnormality herewith reported is of interest because it blends three variations, which, taken alone, are not common in one specimen. The specimen is from the left arm of a white woman, 50 years old, whose death was caused by acute aneurysm (No. 1131). It was my good fortune to dissect this arm while a student of anatomy at the Johns Hopkins University, and with the permission of Dr. Mall I report it.

The axillary and brachial arteries are normal in arrangement until the middle third of the arm is reached. Then between the middle and lower thirds of the arm the artery divides into the ulnar and radial arteries, which are about equal in size. These branches continued somewhat separated until they passed the elbow, when they came in apposition and anastomosed by an opening about as large as the lumen of either of the arteries. The accompanying figure, which is drawn at one-fourth scale, shows the dimensions, form and relation of the arteries. The anastomoses with the posterior ulnar recurrent and anastomotica magna are also shown.

A specimen in the Army Medical Museum at Washington, prepared by Dr. D. S. Lamb, shows a similar variation, high division of the brachial artery with partial reunion at the usual site of its bifurcation into the radial and ulnar. Similar cases are also reported by Quain,[1] Henle,[2] Tiedemann,[3] Power,[4] Green,[5] Maestre [6] and others, which together indicate that there must be some force which favors the bifurcation of the brachial artery at the elbow and that if it bifurcates higher this same force has a tendency to reunite the branches as shown in these cases.

Without entering into the discussion of the arteries of the early embryo, it may be noted that in their later development those arteries which are more favored are preserved. Such branches pass to the ulnar and radial muscle masses and then are arranged on either side of the humerus and later slide down to the forearm. In case the brachial artery bifurcates while the muscle masses are high and obstacles are then placed between the two branches, the condition continues during life. If the bifurcation is low, say the lower third of the humerus, there is no marked obstacle, and by a process of union and shifting the two arteries may unite until they reach an obstacle, which is at the usual point of division. For this reason a bifurcation in the lower third of the upper arm is rare. In this case some obstacle prevented such a union all the way down, but since these arteries were again close together at the usual point of bifurcation, one of the many small branches which united them at this point in the embryo enlarged, for it was "put into use frequently," so to speak. From this time on there was a balance which favored the circulation first through one of the channels of the bifurcation and then through the other, which of necessity caused blood to flow through the anastomosis. Had this not been so, one of the

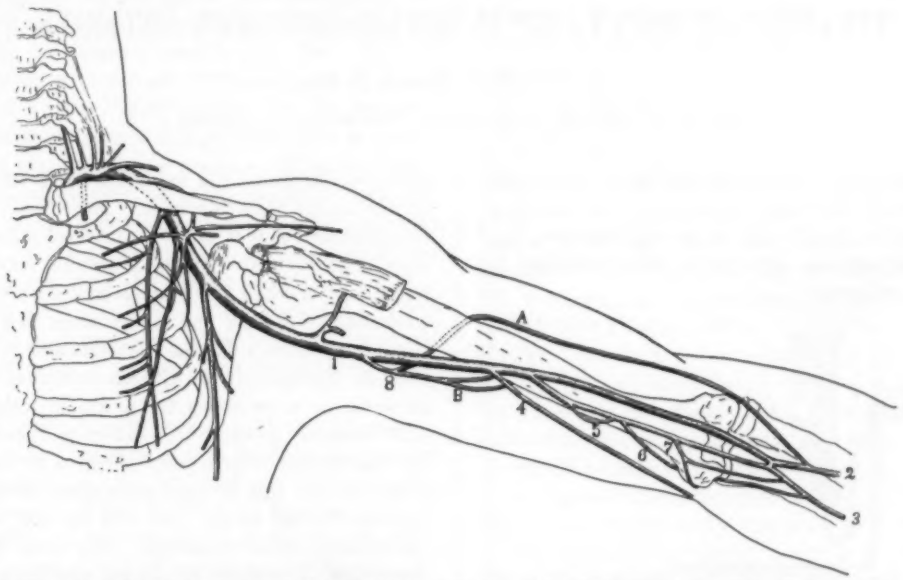

FIG. 1.—Outline of the Brachial Artery and its Branches. Reduced. 1, brachial artery; 2, radial; 3, ulnar; 4, branch accompanying ulnar vein; 5 and 6, branches anastomosing with the posterior ulnar recurrent and anastomotica magna; 7, anastomotica; 8, superior profunda; A, branch accompanying the musculospiral nerve; B, branches to muscles and the anastomoses around the elbow joint.

two channels would have been obliterated or the anastomosis would have closed, as under similar conditions the foramen ovale, ductus arteriosus and other vessels become obliterated.

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4. Power, J. H. Anatomy of the Arteries of the Human Body. Phila., 1863.

5. Green, P. H.: An Account of the Varieties in the Arterial System of the Human Body. Dublin, 1830.

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A preparation by D. S. Lamb, Act. Asst. Surg. U. S. A., in the Army Medical Museum is that of a dissected and injected right arm showing high division of the brachial artery with partial reunion at the usual site of bifurcation into the radial and ulnar.

FIXATION OF TISSUES BY INJECTION INTO THE ARTERIES.

By Burton D. Myers, M. D.,

Associate Professor of Anatomy, University of Indiana.

During the past year, while preparing tissues for the course in histology at Johns Hopkins University, the injection method recommended by McFarland[1] of Leland Stanford, Jr., University, was given a trial. The result was so excellent as to lead to its continued use.

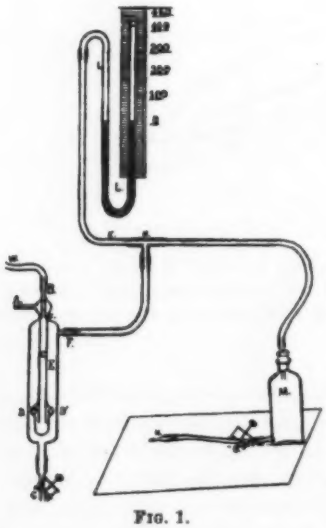

Fig. 1.

The method as suggested by McFarland is very simple. Two bottles with an outlet near the bottom are fitted up with tubes and clamps. This system is to be run up by means of rope and pulley to such a height as will give the gravity pressure required. Simple as the method is, it is very effective. It has, however, the disadvantage of being somewhat inconvenient to handle, and of giving no satisfactory registration of the pressure used, for the pressure varies not alone with the height of the injection flask, but with the specific gravity of the injection mass. Moreover, the method is such an excellent one that some of the more expensive fixing agents were experimented with, which would have been out of the question if one had to fill up an extensive injection apparatus, consisting of a flask and six or seven feet of rubber tubing, with so expensive a fixer as Hermann's fluid, for instance. Still further, it is entirely too difficult to keep so extensive a system as warm as is necessary for a fine injection of blood-vessels with carmine gelatin. Therefore connection was made, in the laboratory, with a very effective air-blast run by water pressure, and this in turn gave place to the inexpensive apparatus figured below. As will be seen readily, the figure illustrates a blast apparatus. The tube *W*, leading from a water tap, is attached to a glass tube *B*, a part of the apparatus. This glass tube *B* ends at *x*, a constricted portion of a chamber to which the air has free access through the tube *A*. Water passing through the system leaves the tube *B* at *x*, drawing along with it a quantity of air into the tube *C*. The force of the water in this tube *C* is broken by the cap at its lower end, and the water and air escape through the openings *D* and *D'* into the chamber *E*, out of which there are but two ways of escape, one at *F* and the other at *G*. The escape of the water at *G* is regulated by a screw clamp according to the air pressure desired. In the chamber *E*, the air, of course, rises to escape at *F* through the rubber tubing connecting *F* with the *T* tube interposed at *H*, through one arm of which connection is established, *J*, with the injection flask *M*, and through the arm *K* connection is made with the mercury manometer *L*.

It is obvious that in the chamber *E* and in the tubes *F J K* and in the flask *M* the air pressure is the same, and will be registered on the millimeter scale placed back of the open leg of the manometer.

On this scale the reading is doubled, for the mercury falls

[1] Jour. of App. Microscopy, Vol. II, No. 10.

in the closed as much as it rises in the open arm, and the difference between the columns is the sum of the rise plus the fall, or double the rise.

Let us suppose our animal, preferably a young one, killed, the artery exposed, and the ligatures in place ready for tying in the glass canula *N*. Let us suppose the injection flask filled with 300 or 400 cc. of normal salt solution heated to 38 or 40° *C.*, and the cork in place, through which, by means of a glass tube, connection between *J* and *M* is established. Now loosen the screw clamp at *O* just enough to let the 12-inch tube and the canula *N* fill with the injection mass and drive out all the air. Now cut the artery, insert the canula and tie it in place. Then cut one of the large veins, say the inferior vena cava, to permit the washing out of the vessels, turn on the water at the tap and loosen the clamp at *O*. If only a little water is turned on, the water and most of the air escape at *G* and the air pressure remains very low. Even if the full water pressure is turned on, if the escape at *G* is too free, considerable air escapes that way and the air pressure remains low. Therefore, when a good flow of water is established, gradually tighten the screw clamp at *G*, at the same time watching the manometer; the water begins to back up in the chamber *E*, escape for the air at *G* is cut off, and the air pressure rises. Thus a balance may be established between the water pressure used and the air pressure.

If the water in the chamber *E* rises much beyond the openings *D D'*, the clamp at *G* must be loosened a bit, or the water will back up into the tubes *F K J* and then over into the flask *M*.

The limit of the pressure to be secured with this apparatus depends upon the water pressure, which, however, is usually much greater than should be used for injection. It is usually possible to get a pressure of 240 to 250 mm. mercury, i. e., a 5-pound pressure, and as a rule one-fourth of this is sufficient.

When the vascular system is well washed out by the normal salt solution, clamp off the flow at *O*, turn off the water at the tap, pour out the remaining normal salt solution, fill the flask as full as desired with the fixing agent heated to 40° *C.*, and again begin the injection.

With this method any rapid fixer may be made use of. It is not always necessary to wash out the blood-vessels with normal salt solution. Fixation is usually better, however, for having done so. With mercuric bichloride it does not so much matter. With formalin and Hermann's fluid, however, it is advantageous for fine fixation. The best fixers have proven to be mercuric bichloride, formalin, Hermann's fluid, and alcohol.

By this method the tissues, after a few minutes bath in warm normal salt solution, are instantly penetrated to the last cell by the fixing agent. The advantages are very great. The tissues, within a few minutes after anæsthetizing the animal (for anæsthetizing, illuminating gas is recommended as being cheap, and causing no salivation), are perfectly fixed in a normal position, at normal distention, and during normal activity. The possibility of post-mortem changes in the central nervous system is practically eliminated. The processes of digestion and absorption are arrested and fixed in the act, and tissues may thus be secured in any desired stage of physiological activity. Engorged tissues are caught with the blood in them, giving a picture of rare beauty. Blood and bone marrow are perfectly fixed.

For studying bone marrow the ribs of a kitten or baby rabbit fixed with $HgCl_2$ will decalcify over night in a solution of 3 per cent HNO_3 made up with 67 per cent alcohol, and from such ribs, sections 3½μ may be secured easily, giving a picture of bone marrow with its connective-tissue framework normally distended and marrow elements in normal position. On sections so thin an oil immersion objective may be used, blood stains employed, and eosinophilic cells in great numbers may be demonstrated outside the blood-vessels of the bone marrow. Particularly are these marrow elements, together with nucleated red blood corpuscles, shown with great beauty in the ribs of a 10-cm. embryo pig. Bone marrow in this form is a decidedly different tissue from bone marrow studied as a smear.

The thoracic wall of a small white rat, fixed by injection of Hermann's fluid, may be cut at 3½μ without decalcification, and, stained with iron hematoxylin, shows not only marrow elements, but the intercostal muscles and nerves in normal position with the usual beauty of a Hermann's fluid fixation. In short, we get a penetration with Hermann's fluid impossible by the ordinary method of using it.

There is scarcely a tissue that is not shown with new beauty by this method of fixation. Sections of lung fixed by $HgCl_2$ injection and cut at 3½μ give a picture unequalled in beauty. The epithelial lining is intact and shows the more perfectly in that the tissue is at normal distention.

A brain fixed and hardened in situ presents a very different appearance from a brain supported on a sheet of cotton.

The method is invaluable not only in preparing tissues for classes in histology, but also as a research method.

In the use of $HgCl_2$ as a fixer by the usual method, the crystalline deposits formed are very annoying and detract from the value of the fixer. This difficulty is overcome in the simplest manner. At a pressure 130 mm. mercury, 400 cc. of a saturated aqueous solution of $HgCl_2$ are injected in about 10 minutes into a small kitten or rabbit, the time depending somewhat on the freeness of the venous opening. If the venous opening is not sufficiently free an œdema is likely to be caused, which in some cases is no disadvantage. Follow the injection of the $HgCl_2$ by an injection of 500 cc. of 67 per cent alcohol. This not merely washes out the $HgCl_2$, but the $HgCl_2$ is about 3 times as soluble in alcohol of this strength as in water, so the washing out is doubly effective and the hardening of the tissue is begun at the same time. After such a washing out, if properly done, one may cut out whatever tissues desired without blackening the knife or tissues. It is usually best to leave the tissues in 67 per cent alcohol for one day, though, if necessary, they may be transferred at once to 82 per cent alcohol after having been washed out with 67 per cent alcohol.

It is found best to inject only one-half an animal at once. The canula should be placed in the abdominal aorta with the mouth just above the cœliac axis when injecting the thoracic viscera and head and neck, and low down in the thoracic aorta when injecting the abdominal viscera. In either case the vena cava should be opened either above or below the liver. It is best to place a block under the back of the animal to insure a free venous outflow.

If the animal is rare or valuable, a double canula may be placed in the abdominal aorta and the whole animal injected at once. After such an injection the whole animal, or the part injected may be left over night in 67 per cent alcohol and then removed to 82 per cent alcohol, which should be changed a few times. Thus a great deal of tissue, excellently prepared in a very short time, may be had on hand for any emergency.

The inner ear of a guinea pig fixed by $HgCl_2$ injection gives a rarely fine picture on section. After decalcification the cochlea should be laid open by a section passing through the modiolus. This permits better infiltration and imbedding, with the result that the delicate membranes are held in position by the celloidin when cut and do not present the appearance so often seen of having been dragged.

Tincture of iodine added to the 67 per cent alcohol used in washing out the $HgCl_2$ showed no noticeable advantage.

A very valuable use of the method is in the preserving of brain tissue. A brain may be fixed in situ by formalin injection, and then removed, the brain stem cut out and placed in potassium dichromate solutions preparatory to sectioning and staining by the Weigert-Pal method. Those who have had the disappointment of having such post-mortem changes take place in the inner capsule and pyramidal tracts, before the penetration of the fixer, as to render the tissue useless, will appreciate the value of this procedure.

Though many uses of the method have been noted they are but a part of the many ways in which the method was found very valuable in the Anatomical Laboratory of the Johns Hopkins University during the past year.

A CONVENIENT STILL TO MAKE ABSOLUTE ALCOHOL.

By William J. Calvert, M. D.,

Assistant Professor of Internal Medicine, University of Missouri.

In 1895, while working in the Anatomical Laboratory of the Johns Hopkins University, it occurred to me that the home manufacture of absolute alcohol would be more economical and satisfactory than buying it in small quantities. With permission from Dr. F. P. Mall, a small still was made which for a time gave satisfactory results. This apparatus consisted of an ordinary tin can and an inverted Liebig's condenser for the first portion of the work. When ready for distillation the condenser was changed to the inclined position and the alcohol was caught in an ordinary receiver. While this apparatus gave satisfactory results, it required more care and knowledge for its operation than can ordinarily be placed in an average janitor, already busy with numberless small chores. Since then, an absolute alcohol still has been constructed by Dr. Mall, which requires practically no care or thought on the part of the operator, yields an excellent quality of alcohol, and is inexpensive. The apparatus is made of heavy copper, tinned on the inside, and a block-tin worm. It is composed of a gas-stove, an automatic water-bath, boiler, condenser, and receiver. (Figs. 1 and 5.)

The only especial requisite for the gas-stove is a stop-cock in the supply pipe by which the gas flow may be regulated, thus permitting the stop-cock in the gas main to be turned on full. A stove similar to No. 8157, Eimer and Amend's Catalogue, 1902, p. 211, is satisfactory.

Naturally the size of the still must depend on the amount of work to be done. For making an amount of absolute alcohol used in our universities the following dimensions are sufficient: a water-bath, eleven inches in diameter and eleven and one-half inches high, with a substantial support one and one-half inches above its bottom to support the boiler and still, will allow one and one-half inches of water about the sides and bottom of a boiler eight inches in diameter and ten inches high. The support for the boiler should be fastened to the sides and bottom of the bath, with a small depression on the upper surface or several small uprights to hold the boiler in one place. The automatic water supply now used on the ordinary water-bath in chemical laboratories is sufficient. The connecting tube *U* should be three-fourths of an inch in diameter and not longer than one-fourth of an inch, placed four inches above the bottom of the bath. The tube *V* should be one inch in diameter, extend from a point level with top of bath to a point one inch below lower side of tube *U*, and be well anchored to side of water-bath, near the top. Supply tube *X*, Fig. 4, sufficiently large to take a one-half inch rubber tube, is inserted at a right angle into the posterior side of tube *V* two inches from top. One-fourth of an inch from tube *V* tube *X* is bent downward at an angle of 45°; this is to prevent kinking of rubber tube connecting *X* with *C*. The height of the water in *V* is regulated by height of tube *W*, which is either fastened in *V* by penetrating a cork stopper or permanently fixed in a cap to screw on *V*. Tube *W* should extend to one inch below top of *V*, and its lower end should accommodate a one-half inch rubber tube which carries waste water to a sink.

The boiler (Figs. 1 and 5) is eight inches in diameter

and ten inches high from bottom to side *Q*, which may slope inward and upward at any desired angle. The opening *P* to *P'* should be at least four inches; walls of neck *N* may be parallel or slightly flared at top and two inches high. At top of *N* a heavy flange *M* three-fourths of an inch wide is firmly attached. The top is composed of wall *O* which closely fits into neck *N* and extends about one-quarter of an inch below the point *P* and *P'*, with the lower edge slightly flanged inward as shown in the figure, to prevent, as far as possible, capillary attraction between the walls *O* and *N*. At the top of *O* a flange *L*, corresponding to flange *M*, is firmly attached, a sufficient distance above *M* to admit a rubber or asbestos ring. The top may then be firmly fastened to the boiler by placing

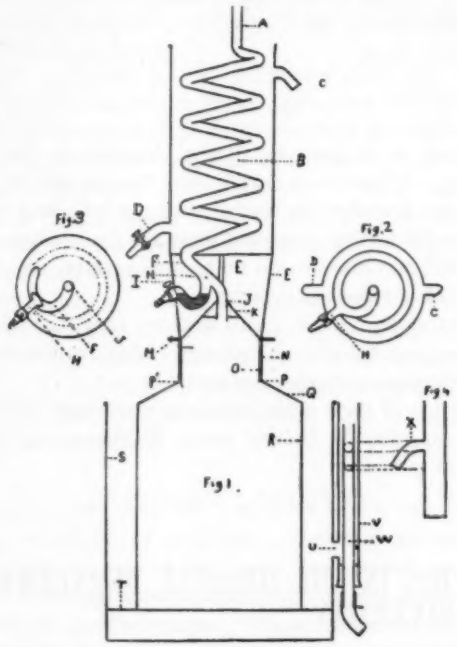

FIG. 1. Median section through the still.

FIG. 2 shows relative position between tube *H*, *D* and *C*. If the still is placed near or against a wall, tube *H* should be a little in front of the plane through *D* so that the cock *I* may be more easily reached.

FIG. 3 shows course of block-tin worm from bottom of condenser to *J* in Fig. 1, seen from below upward.

FIG. 4 is a side view of *V*, showing tube *X*.

several simple clamps on flanges. Beginning at top of *O*, the wall *K* extends upward, cone shaped, to an apex *J*, through which passes the lower end of the block-tin worm *A*. This joint will be more secure if the tin tube extends about one inch below the apex and is braced as shown in Fig. 1. Immediately above the point *J* the tin tube bends at almost a right angle and runs in a spiral direction outward and upward to the bottom of the condenser *B*, the bottom of which should be about one and one-half inches above the point *J*. The spiral tube is shown in Figs. 2 and 3. In the middle third of tube *F*, Fig. 3, is soldered a short piece of tin tubing, in which a stop-cock *I* is placed, in such a manner as to form a small trap in the bottom of tube *F*, which must be filled before the alcohol, returning from the condenser, can flow back to the boiler, Fig. 3. This trap is made by removing the bottom and spreading the sides of tube *F* to receive tube *H*. Tube *H*, in Fig. 3, contains a stop-cock, which, when closed, causes the return alcohol from the condenser to fill the trap and flow into the boiler and when open permits the return alcohol to flow through tube *H* to the absolute alcohol receiver. The lower end of tube *H* is to receive a three-eighths rubber tube, which in turn connects with a glass tube the lower end of which penetrates a cork in the absolute alcohol receiver, which is an ordinary large bottle.

The worm should be of one-half inch block-tin tubing, the coils of which should be from one and one-half to two inches

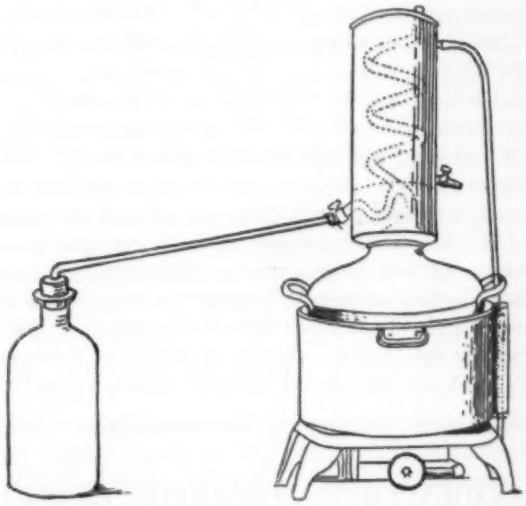

FIG. 5.—Side view of still, one-fourth scale.

apart and three-fourths of an inch from the walls of condenser *B*. When the coil reaches the top of condenser *B*, it should be deflected until the wall of the condenser is reached, here securely fastened and then extend perpendicularly upward four or five inches. Condenser *B* should be at least five inches in diameter and ten inches high, and firmly attached to top *K* by four supports, *E*, *E'*, *E''*. It is necessary to have condenser and top *K* one rigid piece to prevent straining the block-tin tube and disarranging the trap in tube *F*. Near the bottom of the condenser is a cold water intake *O*, for three-eighths rubber tubing, with stop-cock. On the opposite side one inch from top of condenser is an outflow pipe, *C*, for a one-half inch rubber tube. One-fourth of an inch from condenser, tubes *C* and *D* are deflected at 45° to prevent tubing from kinking. Across the top of condenser run two bars at right angles for supporting a handle to which is attached a rope which runs over a small pulley fixed in a bracket a few inches above the condenser. By means of this rope and pulley the condenser is raised so that the wall *O* of top clears wall *N*

of boiler and is then pushed to one side, so the boiler may be removed from the bath for cleaning and refilling. If the condenser is thus handled there is no danger of injuring the joint between *O* and *N*. The rubber tubing connecting the intake *D* with the water main and tube *C* with tube *X* must be sufficiently long to permit the condenser to swing free of the boiler.

The cheapest method of abstracting water from alcohol is by using fresh well burnt lime, quick lime according to the formula $CaO + H_2O = Ca(OH)_2$, which when expressed in atomic weight values is 55.85; 17.95 or 3.11 grams of quick lime for each gram of water. Ordinary commercial 95 per cent alcohol varies from 92 to 95 per cent alcohol, so contains from 5 to 8 grams of water per 100 cc. For safety it is best to calculate 5 grams of lime for each gram of water and allow for 10 cc. of water per 100 cc. of alcohol. On this basis it requires 500 grams of lime per liter or about four pounds of lime per gallon of alcohol.

Directions for operating the apparatus: The boiler is three-fourths filled with lime and 95 per cent alcohol, placed in the water bath, tightly connected with the condenser and allowed to stand over night. On the following morning the bath is heated to, and kept at, about 90° to 93° C. During the first two or three trials the stove must be regulated by the stop-cock in the gas stove, keeping the valve at the gas main open full. When the gas supply has been regulated the valve in stove must remain untouched. The supply of water is regulated by the valve at *D*, keeping the valve on the water main open full. In this way when the apparatus is to be used instructions are to put — grams or pounds of lime and — quarts of 95 per cent alcohol in boiler, tightly connect boiler and condenser, close valve *I*, allow to stand over night, in morning open water main valve and gas main valve full, light stove; in afternoon, shut off gas and water; next morning open water main and gas main valve full, light stove and open valve *I*. When alcohol ceases to flow into absolute alcohol receiver remove and tightly cork the absolute alcohol and immediately clean the boiler. If the lime is allowed to remain in boiler it may be difficult to remove.

Cost of absolute alcohol made in this way is about as follows. From 50 to 75 per cent of 95 per cent alcohol is recovered as absolute:

1 gallon absolute costs,	
2 gallons of 95 per cent, at 50 cents . . .	$1.00
8 lbs. of lime at from 3 to 4 cents	.24
About 100 ft. gas	.15
Water, about	.10
	$1.49

The cost in 95 per cent alcohol depends on the care in operating. If too much heat is used the loss will be greater. During the first day the alcohol need not boil, as a temperature near the boiling point will complete the reaction.

This still may also be used for making extracts, etc., and can be made of any desired capacity.

If the trap pictured in Fig. 3 be blown in a glass tube which could be connected with an ordinary Liebig's condenser a very convenient chemical apparatus would be had.

A number of these stills have been manufactured by Vaile and Young, 210 N. Calvert street, Baltimore, at a cost of about $25 each.

ANNOUNCEMENT CONCERNING GRADUATE INSTRUCTION IN THE MEDICAL DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY.

By W. H. Howell, M. D.,

Dean of the Medical Faculty.

The courses that have been offered to graduates in medicine by the Johns Hopkins University, since the opening of the Hospital in 1889, consisted in the beginning of a combination of general courses, laboratory and clinical, so arranged as to give systematic instruction to large groups of students. In recent years these courses have been given only during the months of May and June, and it has been found desirable to supplant the general courses, to a large extent, by special courses confined to a limited number of students. Although designated as graduate courses, the instruction has been for the most part of an elementary character, especially in the laboratory work, as many of those who entered had not enjoyed the advantages of a training in modern scientific methods. Our experience during the last few years, however, leads us to believe that at present there is no great need on the part of graduates for elementary courses of this character. The wide adoption of laboratory methods in all of our reputable medical colleges, and the general improvement in medical instruction that has been going on for a number of years past, have produced a better trained body of graduates, and those who desire to take post-graduate work are, as a rule, prepared for more special and advanced instruction. The Medical Faculty of the Johns Hopkins University believe, therefore, that the time has come to make specific provision for a higher grade of instruction to medical graduates. They have decided to abandon for the most part those systematic courses heretofore given in May and June, of which the chief aim was to supplement deficiencies in previous training. As a substitute for these May and June courses they propose to offer opportunities of a wider character which, while still

giving to those who so desire a chance to obtain elementary instruction, are especially intended to encourage the development of truly graduate work, such as can be accomplished most satisfactorily by individual study under competent direction. Specific regulations along these lines have been adopted and will be stated in full in the next annual announcement.

For the information of those who may desire to avail themselves of the facilities of the Medical School and the Hospital during the present session, it may be said that these regulations make possible the following opportunities:

1. In each department a limited number of graduates will be received during the whole or a part of the year, either to engage in advanced work of an individual character or to enter the regular courses given to undergraduates. Applications to enter upon such work should be made directly to the Head of the Department.

2. Each instructor in the Medical School may offer to graduates special courses in his subject at any time during the year. These courses may be similar to those heretofore offered during May and June only, that is, courses of a more or less elementary character, but limited to a small number of students so that personal supervision may be obtained from the instructor, or they may be arranged only for those who are prepared to do advanced work.

For the present the following courses may be announced. Those coming under the first group described are designated as University Courses, while those of shorter duration, coming under the second head, are designated as Special Courses. For further details, application may be made to the Dean of the Medical Department.

UNIVERSITY COURSES.

These courses are of two kinds, elementary and advanced. The elementary courses will cover the subject as usually given to undergraduates in medicine and the work may be done with the medical classes. The advanced courses will be given only to those who are prepared to undertake special studies, and the work will be done under the personal supervision of the instructor in charge of the course.

MEDICINE, *Elementary.* A limited number of physicians will be admitted to the regular class exercises in this subject, including ward rounds, clinics and work in the clinical laboratory. Fee $100.00 for the entire year; $50.00 for a half year. Applications should be made to Professor Osler.

MEDICINE, *Advanced.* Physicians properly trained in the methods of clinical diagnosis will be given opportunities for experimental investigation in the clinical laboratory. Fee $50.00 for the year. Applications should be made to Dr. C. P. Emerson.

GYNECOLOGICAL PATHOLOGY, *Elementary.* (Limited to three students.) Drs. Cullen and Hurdon.

The work in this course begins October 1 and extends to May 1. The class meets Tuesdays and Thursdays, 12 m. to 1 p. m. Fee $50.00. Applications for this course should be sent to Professor T. S. Cullen not later than September 15.

OBSTETRICS, *Advanced.* A limited number of physicians will be received for advanced instruction under Professor Williams during the Academic year—October to June. Those intending to enter upon this work should apply to Professor Williams stating the character of the work they desire and their qualifications for undertaking it. Fee $50.00

PATHOLOGY OF THE HEART AND CIRCULATORY SYSTEM, *Advanced.* (Limited to five students.) Professor W. G. MacCallum. The course will begin October 9 and continue for five weeks, with three exercises a week.

These exercises will consist of lectures, experiments on animals, and anatomical, chemical and microscopical demonstrations. The following topics will be considered: Diseases of the pericardium, diseases of the endocardium and myocardium, pathology of the pulmonary circulation, pathology of the systemic circulation, pathology of the lymphatic channels. Fee $30.00. Those desiring to take the course should correspond directly with Professor MacCallum.

PATHOLOGY, *Elementary.* A limited number of physicians will be received during the year in the courses in bacteriology and pathology. Fee for the entire year $50.00, fee for half year $25.00. Apply to Professor W. H. Welch.

PHARMACOLOGY AND TOXICOLOGY, *Elementary.* January 1 to June.

A limited number of physicians will be received into the regular course as outlined in the catalogue of the Medical School. Fee $25.00. Apply to Professor J. J. Abel.

PHARMACOLOGY AND TOXICOLOGY, *Advanced.* Professor Abel.

Those who have had the necessary preliminary training and who desire to do work of a special character will be received at any time during the Academic year. Fee $50.00 for the entire year.

PHYSIOLOGY, *Elementary.* (Limited to four.) Laboratory course in experimental physiology, October to December 25.

The work will consist in exercises in the various graphic methods used in physiology to study the properties of muscle and nerve and the circulatory and the respiratory organs. Fee $25.00. Apply to Professor W. H. Howell.

PHYSIOLOGY, *Advanced.* (Limited to two.) January to June 1. Professor Howell.

Individual instruction will be given in the methods used in physiological demonstrations and research. Especial attention will be paid to the methods employed in the study of the circulation. Fee $50.00.

ANATOMY, *Advanced.* Those who have had the necessary preliminary training and desire to undertake the study of special problems, will be received at any time during the Academic year. Fee $25.00. Apply to Professor F. P. Mall.

HISTOLOGY AND ORGANOLOGY, *Elementary.* Professor Harrison, Drs. Sabin and Knower, October 1 to February 15, Monday, Wednesday and Friday afternoons. (Limited to three.) Fee $50.00.

NEUROLOGY, *Elementary.* A systematic course in the gross and microscopic anatomy of the central nervous system, from February 1 to March 15. Lectures, Dr. Sabin, three hours a week; laboratory work, Dr. Sabin, Professor Harrison, Drs. Knower and Streeter, Monday, Wednesday and Friday afternoons. (Limited to five.) Fee $25.00.

NEUROLOGY, *Advanced.* (Limited to two.) Dr. Sabin, March 15 to June 1, forenoons.

The work will take up special topics in the development and structure of the central nervous system. Fee $25.00.

NEUROLOGICAL TECHNIQUE, *Advanced.* (Limited to two.) Dr. Streeter, March 15 to June 1. A knowledge of general histological technique will be assumed. Fee $25.00.

EMBRYOLOGY, *Elementary.* (Limited to two.) Dr. Knower, March 15 to June 1.

A laboratory course in the development of the mammalian body as illustrated by pig and human embryos. Fee $25.00.

HUMAN EMBRYOLOGY, *Advanced.* Professor F. P. Mall, October 1 to June 1. (Limited to two.) Fee $25.00.

EXPERIMENTAL EMBRYOLOGY, *Advanced and Research.* Professor Harrison, March 15 to June 1. (Limited to two.) Fee $25.00.

PHYSIOLOGICAL CHEMISTRY, *Elementary.* March 15 to June 1, every afternoon.

A limited number of physicians or others who have had the requisite preliminary training in chemistry will be received for the laboratory course and lectures given to the medical students. Fee $25.00. Apply to Professor Walter Jones.

PHYSIOLOGICAL CHEMISTRY, *Advanced.* Professors Abel and Jones.

Those who have the necessary preliminary training and who desire to do work of a special character will be received at any time during the Academic year. Fee $50.00, for the entire year.

SPECIAL COURSES.

MEDICINE. Drs. McCrae, Cole and Boggs, June 1 to July 1. (Limited to fifteen.) Fee $100.00.

The course will not be given if less than eight register. Applications for this course must be sent in not later than May 10.

The whole material of the medical service will be available for the class. Special attention will be given to the study of the general methods used in the clinic.

The course consists of:

I. *Ward Rounds.* Drs. McCrae and Cole, from 9 to 11 daily. Special attention will be given to diseases of the circulatory and digestive systems.

II. *Physical Diagnosis.* Dr. McCrae, five hours a week. The general methods of diagnosis will be taken up and special attention given to diseases of the thoracic and abdominal organs.

III. *Clinical Microscopy and Medical Bacteriology.* Dr. Boggs, three afternoons—9 hours a week. This course consists of lectures, demonstrations and especially of practical work. All of the available specimens of blood, urine, sputum, gastric contents and stools are studied. The ordinary methods of clinical bacteriology will be demonstrated.

PEDIATRICS. Dr. S. Amberg, June 1 to August 1, daily from 11 to 12, Dispensary. (Limited to eight.) Fee $40.00. The participants are expected to examine patients personally under supervision.

SURGICAL PATHOLOGY. Professor Bloodgood. This course is given three times during the year, as follows: Course I, October 10 to December 20; Course II, January 10 to April 20; Course III, May 2 to June 30. (Each course will be limited to twelve.) Fee $50.00.

The course consists of:

a. Systematic instruction in clinical and pathological diagnosis, illustrated by pamphlets, photographs, museum specimens, and microscopic sections.

b. Demonstrations on all fresh material received in the Surgical Pathological Laboratory.

Demonstrations, October to May, Tuesdays, 2:30 p. m. to 4:30 p. m.; Wednesdays and Fridays, 1:30 to 2:30 p. m. Demonstrations in May and June, Tuesdays, Thursdays and Fridays, 8 to 9 a. m. Students taking this course should plan to give at least three hours a day to the work.

OPERATIVE SURGERY ON ANIMALS. Professor Cushing, April 29 to June 21, Wednesdays and Saturdays. Sixteen exercises of from four to five hours each, commencing at 8:30 a. m. (Limited to ten.) Fee $60.00.

The course will be limited to ten graduate students who will be divided into two groups of five, thus making up two complete operating staffs, an operator, first and second assistant, anæsthetist, and attendant. The members of the class rotate in these positions during the various exercises. An effort is made to carry out as closely as possible the same technique that is used in the general operating room of the Hospital. The graduates taking the course do all of the operative work themselves.

Emphasis will be laid upon methods of operating in general, rather than upon any particular operations. A schedule of the exercises showing the operations performed will be furnished on application.

GENITO-URINARY SURGERY. Professor Young. Fee $100.00.

A limited number of graduates will be taken for special work in Genito-Urinary Surgery. The course will include clinical and laboratory work and the student is expected to give his entire time, or most of it, to the department, and to enter for six months or more. Research studies will be encouraged.

ORTHOPEDIC SURGERY. Dr. Baer, May 15 to August 1, Monday, Wednesday, Thursday and Saturday, 10 to 12 m. (Limited to ten.) Fee $50.00.

A course will be given in the Orthopedic Dispensary from 10 to 12 m. on the days noted in which the students will be given practical work in the diagnosis and treatment of all orthopedic affections. Ward rounds covering this class of cases will be made from 9 to 12 on Monday mornings. Opportunities at this and other hospitals will be posted during the course so that one may be able to see practically all orthopedic operations.

X-RAY DIAGNOSIS AND THERAPEUTICS. Dr. Baetjer. This course is given three times during the year as follows: Course I, October 15 to December 15; Course II, January 15 to March 15; Course III, April 15 to June 15. (Limited to five in each course.) Fee for each course, $50.00.

Each course will consist of daily demonstrations from 11 a. m. to 12:30 p. m., and the aim of the course is to give a practical knowledge of the construction of the X-Ray apparatus, and its use in diagnosis and treatment.

GYNECOLOGICAL PATHOLOGY. Professor Cullen, during March and April, Tuesday and Thursday, 12 to 1 p. m. Pathological Laboratory. (Limited to ten.) Fee $50.00.

A course in the diagnosis of uterine scrapings. All pathological conditions of the cervix and body of the uterus that could be mistaken for cancer are discussed, and special consideration is given to the early diagnosis of cancer of the uterus. The methods of obtaining and examining pieces of uterine tissue are given in detail.

CYSTOSCOPIC EXAMINATIONS. Dr. Hunner, Monday and Friday, 2 to 4 p. m. May 12 to July 30, inclusive. (Limited to six.) Fee $50.00.

Fifteen clinics covering the entire subject of diseases of the urinary tract in woman. Demonstrations of the newer instruments used in urinary work.

This course is for beginners in cystoscopy.

BACTERIOLOGY, *Elementary.* Dr. Ford, May 1 to June 1. Three mornings a week. (Limited to ten.) The character of the work will be adapted to the needs of the class. The course will include instruction in: 1. Elementary Bacteriology. 2. Sanitary Bacteriology, including water and milk. 3. Technique of agglutination, hæmolysis and immunization of smaller animals. Fee $50.00.

PATHOLOGY, *Elementary.* Dr. Bunting, May 1 to July 1. (Limited to ten.) Three afternoons a week. Lecture and laboratory exercises in general pathological histology.

The course will not be given if less than five register. Applications must be received before April 15. Fee $50.00.

OPHTHALMOSCOPY AND OPHTHALMOLOGY. Dr. Mills, June 1 to July 1, Monday, Wednesday and Friday, 3 to 4 p. m. (Limited to ten.) Fee $25.00.

This course is intended for general practitioners.

GROSS ANATOMY. Professor Lewis, October 1 to June 1, hours arranged with the instructor. Fee $25.00 per month.

Dissection, study of prepared specimens and of frozen sections.

REGISTRATION.

Before entering upon any of these courses of graduate instruction the student must register at the Office of the Dean of the Medical School. Upon payment of the requisite fees a card will be issued stating the courses which the holder is permitted to take. This card must be presented to the instructor in charge of each course at the beginning of the classwork in order that the holder may be duly recognized as a member of the class.

SUMMARIES OR TITLES OF PAPERS BY MEMBERS OF THE HOSPITAL OR MEDICAL SCHOOL STAFF APPEARING ELSEWHERE THAN IN THE BULLETIN.

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